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INFLUENCE OF THE TECHNOLOGICAL PARAMETERS ON THE DISTRIBUTION OF THE TEMPERATURE FIELD AND THE DEPTH OF THE HARDENED LAYER DURING THE INDUCTION HEATING OF THE INTERNAL CYLINDRICAL SURFACE OF SHIP STEEL BUSHINGS

[1]APRAHAMIAN BOHOS, [2]STREBLAU MAIK, [3]STAVREV DIMITAR, [4]SHTARBAKOV VLADIMIR

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The induction heating is widely used owing to the high quality performance, versatility and precise control means of the heating process. Hardening of internal cylindrical surfaces of ferromagnetic details and achieving preset depth of the hardened layer requires the provision of certain speed of heating and cooling, determinate surface temperature and distribution in depth.
The purpose of this paper is to present a concrete solution for the shape of the inductor, heating the internal surface of a cylindrical detail, such as ship bushing, and simulation of the processes occurring in the system inductor-detail to study the influence of the process parameters on the depth of the hardened layer.

***Keywords**:* induction hardening, hardened layer, modeling an inductor-detail system

1. INTRODUCTION

The heating of the internal cylindrical surfaces and the achievement of preset depth of the hardened layer in ferromagnetic details requires the provision of determined speed of heating and cooling, surface temperature and temperature distribution in depth of the detail [1, 2, 3, 4, 5, 6, 8].

Ensuring the technology requirements determine the need for adjusting the listed parameters and proper choice of the geometry of the inductor.

Otherwise the accompanying electromagnetic effects [7] lead to distorting the electromagnetic link in the system inductor-detail and uneven distribution of the temperature field, respectively, lower process efficiency and quality of the processed details.

The purpose of this paper is based on the results obtained in [9] to provide a specific solution for the form of the inductor for heating the internal surface of a cylindrical detail, such as ship bushing, and a simulation of the processes in the system inductor-detail based on mathematical model to study the influence of process parameters on the depth of the hardened layer.

2. METHODS USED TO INVESTIGATE

Using industrial induction system type GI-25 (made in Russia), rated for 25 kW power and frequency 440 kHz a heat treatment for hardening the internal surface of cylindrical steel bushings was realized. The steel grade is C50 EN 10083-2.

The configuration of the system inductor - detail, the chemical composition of the material and technological requirements are specified in [9]. Since in the realized experiment described in [9], the heat is conducted through an inductor with round section, providing very uneven temperature field, the heat treatment described in this study is through inductor with profile (rectangular) section - Figure 1.

For this purpose it is made of rectangular copper tube with section 7x4 mm, corresponding to round copper tube with diameter Ø6 mm and wall thickness 0.5 mm. The used profile allows to reduce the number of turns in two of three against the proposed configuration in [9].

This determines less inductive reactance of the system and more power in the oscillatory circuit at the same voltage to the experiment discussed in [9].

The air gap of 2 mm stayed the same as in the inductor with round section [9]. The realized system inductor-detail is shown in Figure 2.

Fig. 1. Profile inductor with rectangular section

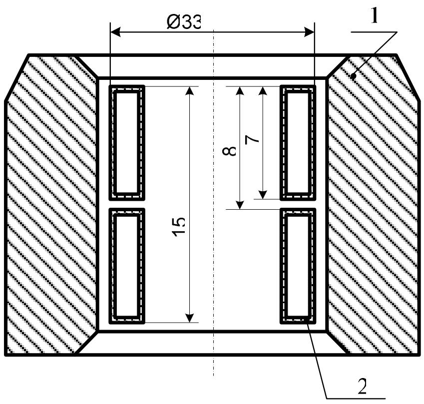

Fig. 2. The realized system profile inductor - detail

Through the system presented in Figure 2 a computer simulation was implemented based on the mathematical model described by equations (1) and (2):

$$\nabla \times \left(\frac{1}{\mu(H,T)} \times \nabla \times \dot{A} \right) + j \cdot \omega \cdot \gamma(T) \cdot \dot{A} = \frac{\gamma \cdot U_C}{L} \tag{1}$$

$$\rho(T)\cdot c(T)\cdot\frac{\partial T}{\partial t}=\nabla(\lambda(T)\cdot\nabla(T))+\frac{1}{2}\cdot\gamma(T)\cdot\omega^2\cdot\dot{A}^2 \qquad (2)$$

where:

A, Wb/m - magnetic vector potential, *Uc, V* - voltage on the inductor, *T, K* - absolute temperature, *μ, H/m* - absolute permeability, depending on the strength of the magnetic field and the temperature, *L, m* - length of the inductor's bare wire, *γ, S/m* - specific electrical conductivity, *t, s* – time, *ρ, kg/m*^{3} - material density, *λ, W/m.K* - thermal conductivity, *c, J/kg.K* - specific heat capacity.

The geometric model of the presented in Figure 2 system is shown in Figure 3. The material properties assigned to the corresponding model fields are given in literature sources [10, 11].

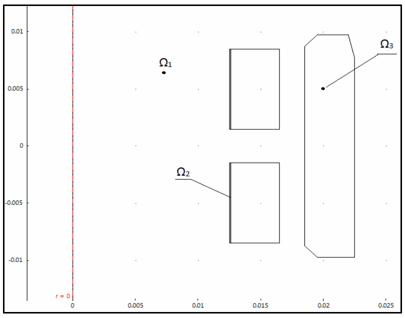

Fig. 3. Geometric model of the system inductor-detail, where: Ω_1 – air, Ω_2 – inductor, Ω_3 - detail

3. RESULTS AND ANALYSIS

The results of the realized theoretically study are related to the ability to obtain uniform temperature field longitudinal the axis of the detail at a specific surface power in the range 0.30 ÷ 0.57 kW/cm^2.

For this purpose are presented the patterns of the electromagnetic and temperature field in the detail - Figure 4, and the temperature distribution on the surface and at depth of the detail - Figure 5.

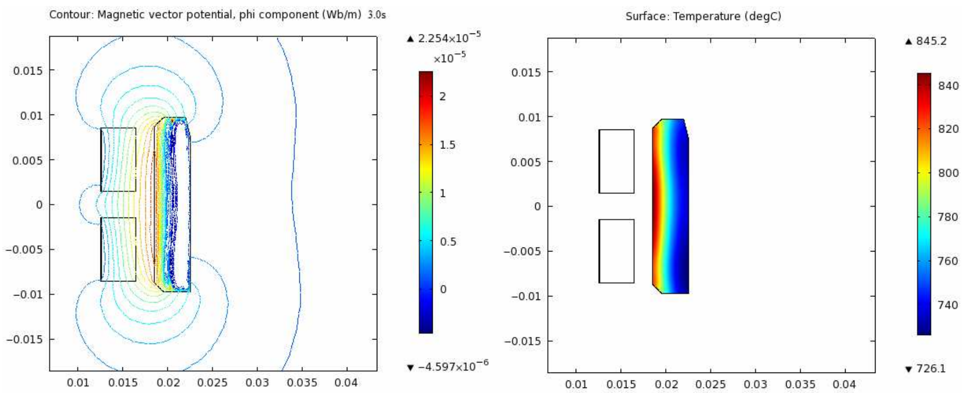

Fig. 4. Distribution of the magnetic vector potential and the temperature field in the profile inductor at specific surface power 0.30 kW/cm^2

Using inductor with rectangular section, compared with the round section one [9], allows the realization of technological regimes of heating the detail, in whom a uniform distribution of the magnetic field - Figure 5, and respectively, the temperature on the surface and at depth of the detail are realized - Figure 5 and Figure 6. For this purpose, simultaneous heating regime is used. The temperature of the detail's surface at 1 ÷ 1.5 mm in depth along the longitudinal axis is in the range of 820-840 ^oC .

Unlike the continuous-sequential regime of heating, this avoids the overheating of the edges of the detail at the beginning and end of the process, corresponding to the introduction and removal of the bushing from the impact of the inductor.

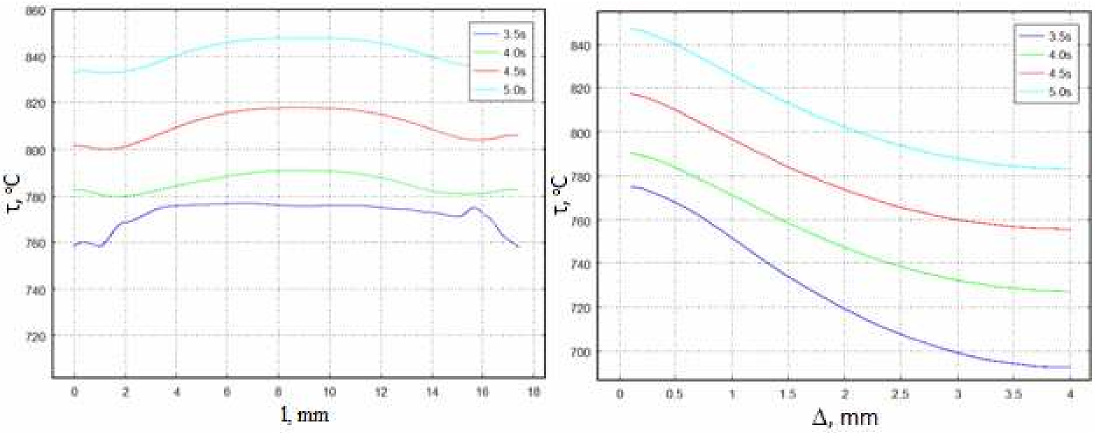

Fig.5. Distribution of the temperature on the surface and in depth of the detail at specific surface power 0.30 kW/cm²

The Figure 6 and Figure 7 show the distribution of the temperature on the longitudinal axis and in depth of the detail for different values of the specific surface power and the time of exposure.

It is important to note that favorable treatment regimes are those in which heat is realized in the temperature range of 820-840^{o}C with uniform temperature distribution along the axis of the processed detail.

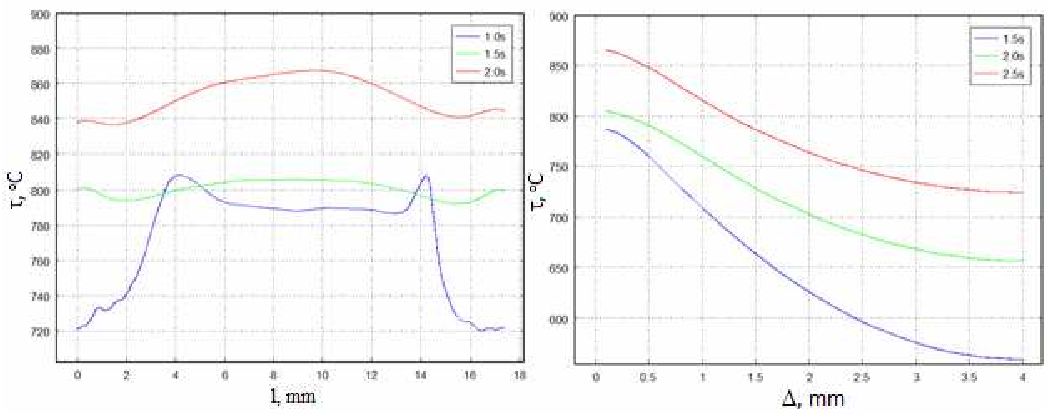

Fig. 6. Distribution of the temperature on the surface and in depth of the detail at specific surface power 0.43 kW/cm²

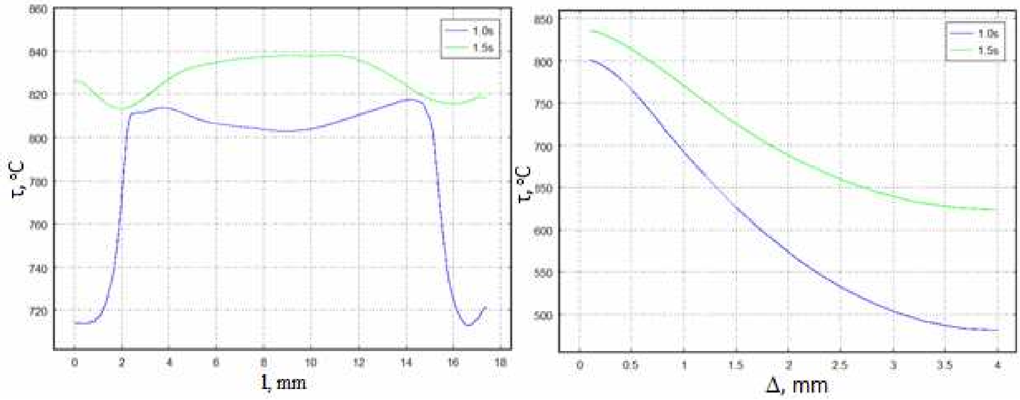

Fig. 7. Distribution of the temperature on the surface and in depth of the detail at specific surface power 0.57 kW/cm²

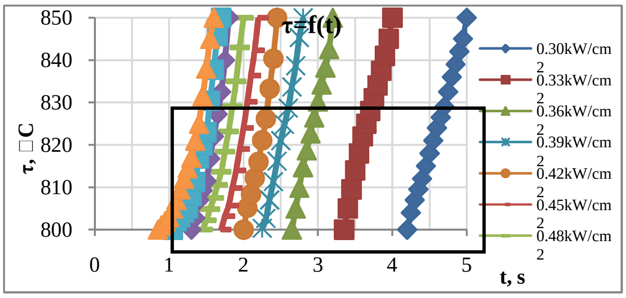

Fig.8. Temperature on the detail's surface, depending on the time of heating and the specific surface power

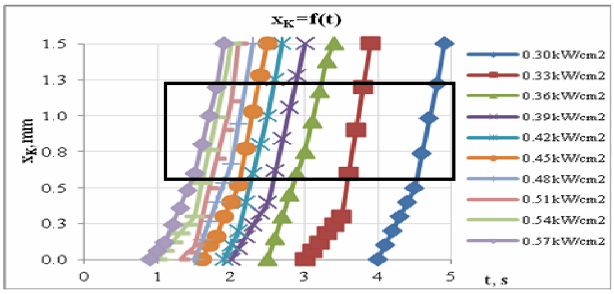

Fig. 9. Values of the depth of the hardened layer depending on the time of heating and the specific surface power

On this basis, are drawed and presented in Figure 8 and Figure 9 the nomograms for optimal selection of the process parameters for the treatment of the internal cylindrical surface of bushing type details.

The graphs in Figures 8 and 9 are referred to the respective values of the temperature on the surface and the depth of hardening depending on the duration of exposure and the specific surface power.

The parameters which realize a thermal cycle effects with achievement of temperatures providing the necessary polymorphic transformations are presented in the fence framed pieces of graphics - Figure 8 and Figure 9.

They meet the technological requirements for necessary geometry and depth of the hardened layer and even distribution along the axis of the processed detail.

4. CONCLUSIONS

In induction heating of internal cylindrical surfaces pivotal role on the distribution of the temperature field in the detail have the accompanying electromagnetic phenomena – coil and end effects. They affect the electromagnetic connection between the elements in the system inductor - detail.

When cylindrical inductors are applied, to reduce the influence of the coil effect is appropriate the use of profile inductors with rectangular section.

The end effects can be reduced by reducing the height of the inductor relative to detail height and with additional slope on the edges.

The application of profile inductors minimizes the impedance of the system that sets a higher specific surface power at the same voltage value compared to similar inductor with round section. The above sets higher efficiency of the induction system and achieves sufficient quality of the processed details.

ACKNOWLEDGEMENT

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A NEW TENDENCY IN EVALUATION THE SHIPS PASSAGE

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Many years in the maritime navigation the main problem was determination and accuracy of ships position. Solving of this problem was with great priority in the methods of evaluating the passage. All theory of navigation and passage planning was built around opportuninies for the Officer of the Watch to determine the ships position on different stages of the passage.Today, in establishing the ships passage plan, the Officer of the Watch has another criterias for evaluating the stages of the passage. Today ships position determination is not a problem at all and the accuracy of the position is very high. Today the International Safety Management Code requires another priorities in the stage of ships passage planning- which are described in the paper.

Keywords: ships passage plan, risk assessment, theory of information.

1. INTRODUCTION

Over the past 20 - 25 years shipping experienced huge technological progress related to constructive development of ships, especially with the development of Ships Bridge, moreover given the rise and technology set out in the safety and reliability of the ship, in relation to navigation. Problematic issues shifted from the field of pure navigation in order to solve problems related to the quality and quantity of information, especially in risk assessment operations.

In terms of theoretical and practical evaluation, navigational sailing includes criteria previously absent from the analysis. Going back to the early 90-ies of the last century it is sein that the main problem was to determine the location of the ship, mostly at sea. High accuracy of the ships positioning was a criteria of knowledge and experience of the officers of the watch. Such accuracy commensurate with the accuracy of modern equipment could be achieved only by experienced officers and extremely precise measurements.

In modern navigation meeting the standards of accuracy of the ships position offered by the IMO and IALA is not very difficult. The work of the Officers of the Watch (OOW) is facilitated by the precision of modern navigation equipment. Today OOW have alternative means for determining the position of the ship. At some stage of the voyage might be a surplus of navigational information. Currently, there is no algorithm that can help the process of separating the necessary information for a given situation.

2. PRIORITIES IN THE NAVIGATION PROCESS

Safety is a top priority for operation of each ship. Today the safety of the ship comes from within the navigation process and has a much wider scope than the activity of determining the position of the ship. For certainty, it is used the entire available flow of information available on the bridge on different levels of management and with different technologies.

In 2010, with the amendments to the ISM Code in shipping, it is applied a methodology for risk assessment of the vessel. This requirement added another field in the navigation process. Risk assessment is applied prior to any activity that adds extra information to the bridge and evaluation of navigation.

Regarding necessary information for safety of navigation nowadays bridge equipment gives enough quantity to the OOW. During the last decade the Integrated Bridge Systems (IBS) have proved to be the major information systems on the navigation bridge. They are the integrating unit of the separate aids to navigation such as the GPS, the radar, the ARPA, the electronic chart and information system (ECDIS), the echo-sounder, the log, the anemometer, etc. The information from all the sensors is collected and processed by the processing unit of the IBS and can be shown on the display by means of separate menus. In this way the OOW obtains data about the position of the dangers to navigation, both under- and above-water, their characteristics and their movement relative to the ship [1, 2].

The navigating officer has to have in mind the features above when prepare the vessels passage plan. Passage appraisal stage is the most important stage in such activity. As Capt. Swift and Capt. Bailey have mentioned in their book, the appraisal stage examine the risk. If alternatives are available, the risks are evaluated and a compromise solution is reached whereby the level of risk is balanced against commercial expediency [3]. In this respect it can be fixed the first priority in the navigation process, i.e. preparing the passage plan with detailed work in the most important stage, passage appraisal.

The state of the system “ship-danger to navigation” is described with the events x_1, x_2, x_3 and x_4, which, under the condition of continuity, have their own laws of distribution.

The position of the ship on the course x_1 is controlled by the continuous calculation of the coordinates φ and λ. The deviation from the course m depends on the accuracy of the fixed position of the ship. Consequently the entropy of the value m will be calculated using the formula [1, 2]:

$$H(m) = \log_2\left[\frac{\sqrt{2\pi\ell}.\sigma_m}{\Delta m}\right] \tag{1}$$

Where: σ_m is the mean square deviation of m, depending on the mean square deviation of the ship’s position;
Δm – error of the calculated distance m as a result from the incorrect plotting of the ship’s course.

The position of the ship in relation to the fixed dangers is determined by the measured distances D_i to them. The entropy of the system X as a result from the event x_2 is calculated using the formula:

$$H(D) = \log_2 \frac{D_0 - D_S}{\Delta D} \tag{2}$$

where ΔD is an error in the measured distance to the target;
D_0 – distance of locating the target;
D_S – distance of safe passing the target.

The closest point of approach for passing moving targets depends on a lot of values distributed as per the Gauss Normal law. Therefore, we shall assume that the entropy of *CPA* (Closest Point of Approach) will be calculated using the formula:

$$H(CPA) = \log_2\left[\frac{\sqrt{2\pi\ell}.\sigma_{CPA}}{\Delta CPA}\right] \tag{3}$$

where σ_{CPA} is the mean square deviation of the calculated *CPA*;

Δ_{CPA} – the deviation of the ship from the course, at which the calculated *CPA* remains unchanged.

The entropy of the measured depth under the keel is calculated using the formula:

$$H(H) = \log_2 \frac{H_2 - H_1}{\Delta H} \tag{4}$$

where H_2, H_1 is an area under the keel with even density of depth distribution;

ΔH – an error in the measured depth.

From the above stated about the entropy of the system X, the following formula is obtained:

$$H(m,,D,CPA,H) = \log_2 \left(\frac{2\pi\ell.\sigma_m.\sigma_{CPA}}{\Delta m.\Delta CPA} . \frac{D_0 - D_S}{\Delta D} . \frac{H_2 - H_1}{\Delta H} \right) \tag{5}$$

The formula (5) takes into account the entropy of the system "ship - dangers to navigation" in case the events x_1, x_2, x_3 and x_4 come true simultaneously. In the actual practice, however, that is very unlikely. Usually preparation of sailing plan takes into account the peculiarities of the region of sailing. Then the most serious dangers to navigation are the moving targets. On another occasion, when sailing in narrow waters, utmost attention is to be paid to the depth under the keel or to the fixed targets. Therefore the formula for the complete information, as found in the events x_1, x_2, x_3 and x_4 will depend on those of them, which are of the greatest probability to occur.

Obtaining information for solution given by formula (5) the OOW, base on his own experience, can predict the danger with priority for the present situation. Many shipping companies have included in their Safety Management System (SMS) risk analysis of pure navigational process. Review of the technology of preparation of such anaysis shows that the quantity and valuability of information are the most important factors.

3. NAVIGATIONAL RISK ASSESSMENT

The International Safety Management Code (ISM Code) requires that all shipping companies must assess all identified risks to their ships, personnel and environment and establish appropriate safeguards [4]. This changes in the company policy cover the formal assessment of the hazards and risks for navigation within the ports and all others areas. Furthermore, the companies must maintain a formal navigational Safety Management System (SMS) developed from that risk assessment.

Analising formula (5) it can be seen that risk of collision, grounding and deviation from the planned trak exist at all time and at all stages of sailing. Such risk can be predicted by the navigating officer in the time of preparation of the passage plan. Today in the shipping the following methods for risk analysis are used: hazard identification technique, what-if analysis and checklist analysis [5]. What is the content of the technics and methods?

- Hazard Identification (HAZID) Technique is a general term used to describe an exercise whose goal is to identify hazards and associated events that have the potential to result in a significant consequence. For example, a HAZID of an offshore petroleum facility may be conducted to identify potential hazards which could result in consequences to personnel (e.g., injuries and fatalities), environmental (oil spills and pollution), and financial assets (e.g., production loss/delay). The HAZID technique can be applied to all or part of a facility or vessel or it can be applied to analyze operational procedures. Typically, the system being evaluated is divided into manageable parts, and a team is led through a brainstorming session (often with the use of checklists) to identify potential hazards associated with each part of the system. This process is usually performed with a team experienced in the design and operation of the facility, and the hazards that are considered significant are prioritized for further evaluation.

- What-if Analysis is a brainstorming approach that uses broad, loosely structured questioning to postulate potential upsets that may result in mishaps or system performance problems and ensure that appropriate safeguards against those problems are in place. This technique relies upon a team of experts brainstorming to generate a comprehensive review and can be used for any activity or system. What-if analysis generates qualitative descriptions of potential problems (in the form of questions and responses) as well as lists of recommendations for preventing problems. It is applicable for almost every type of analysis application, especially those dominated by relatively simple failure scenarios.

It can occasionally be used alone, but most often is used to supplement other, more structured techniques (especially checklist analysis).

- Checklist analysis is a systematic evaluation against pre-established criteria in the form of one or more checklists. It is applicable for high-level or detailed-level analysis and is used primarily to provide structure for interviews, documentation reviews and field inspections of the system being analyzed. The technique generates qualitative lists of conformance and nonconformance determinations with recommendations for correcting non-conformances. Checklist analysis is frequently used as a supplement to or integral part of another method (especially what-if analysis) to address specific requirements.

For the process, it is important to recognize that an effective and comprehensive risk assessment, and indeed the resultant safety management system, can only be achieved with the total commitment of both senior management and those staff involved. There has to be a 'buy-in' by all concerned. Communications (including bottom/up, top/down and where necessary external communication), and openness are vital.

The methods, mentioned above, require information, necessary quantity of which is difficult to evaluate. It depend of the officers experience and good communication between management at all levels and ships administration.

4. CONCLUSIONS

Looking for relation between risk assessment and necessary quantity of information for formal description of the navigational process we can say that there is no relation. For formal description of the navigational process the OOW need not too much information that usually he receive on the ships bridge. The problem at all is classification of that information according to the priority for the moment. The OOW appreciate the priority based on his own experience, which is not under systems control and objective evaluation.

On the other side for risk assessment process bridge team need more information for full description of all hazards, incidents and lessons to be learned. On first site there is a conflict but the practice shows another conclusions. More information is needed for analyzing the navigational process and this information have to be obtained from check lists and non-conformity reports on board. Such information is practically shared experience which is good basis for development of the requirements for risk mitigation.

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PSEUDORANDOM NUMBER GENERATOR

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The paper presents a random numbers generator based on linear feedback shift register (LFSR) and hash function. The development is made under MatLAB and some statistical tests are applied to output sequences. The generator is based on dsPIC microcontroller and has an ability to modulate sine wave by FM and BPSK.

Keywords: random sequences, hash function, LFSR

1. INTRODUCTION

The random and pseudorandom sequence generators (PSG) are a subject of interest in many fields of the scientific knowledge, such as: communication [3, 8], radiolocation [6, 7], cryptography [2, 8, 9], hydroacoustics, etc. There are mainly two types of generators used in said fields: such built on electronic components, some of whose characteristics have random behaviour, or hardware implementation of various algorithmic schemes [1, 2]. The usage of specialized electronic noise elements is related to the use of complex circuit solutions for maintaining stable operation of the generators.

The alternative solution of PSG is the implementation based linear feedback shift registers (LFSR), which find wide application [3, 7, 8]. The high quality in these patterns can only be achieved only at very large lengths (larger than 2^{15} bits). As known, greater length on its own, creates difficulties, associated with finding primitive polynomials of high degree [8,9] and the classical M-sequences are susceptible to cryptography attack of the Berlekamp–Massey algorithm [2, 9].

The following paper offers an implementation of pseudorandom sequences generator, based on LFSR and hash function.

The aim is to improve the quality of PSG based on LFSR with small lengths, while in the same time said disadvantages are minimized.

2. CLASSIC SCHEME

The maximum extended period *P* of the output sequence is a function of the number of different states of the register, as well as its length *n*, and is expressed as follows:

$$P = 2^n - 1 \qquad (1)$$

In a binary notation, the number of bits of relocation register is calculated using the formula:

$$n = \lfloor \log_2(P) \rfloor \quad (2)$$

where n is the length of the register and is measured in bits [b].

The general form of the feedback function must be a primitive polynomial of the n^{th} degree [2, 9]. This polynomial is given by the following formula:

$$q(x) = q_0 + \sum_{i=1}^{n} q_i . x^i \quad (3)$$

where $q_1, q_2, \ldots, q_n$ are recursive coefficients, x is a formal variable of the polynomial. The combination of coefficients q_1 can be seen as a mask that determines the feedback relations of the scheme, since the coefficients are allowed only the values of 0 and 1.

According to the above, PSG realized on the base of LSFR can be presented with the following block scheme:

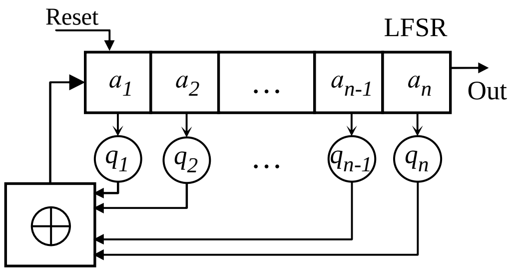

***Fig. 1. Block diagram of LSFR which length is n* [b]**

LSFR is composed of one n bit register, that shifts to the right content, and feedback relations calculated by the formula (3).

The initial state is provided through external Reset signal and loading with selected combination of 0 and 1 where a value of "000 ... 0" is prohibited.

3. THE IDEA OF THE GENERATOR'S SCHEME

In this paper is presented a study of PSG structure using hash function and LFSR.

The structure can be viewed as a modification of the Klapper and Goresky idea for a generator of pseudorandom numbers using external memory [2,10,11]. It is a known fact that the classic generators are constructed on the basics of linear feedback shift registers and are vulnerable to crypto attacks [9]. The added hash function aims to destroy the recurrent connections in the output bit sequence and to bring additional randomization, in result of which the crypto attack is much harder.

The final structure of the generator is shown in Figure 2:

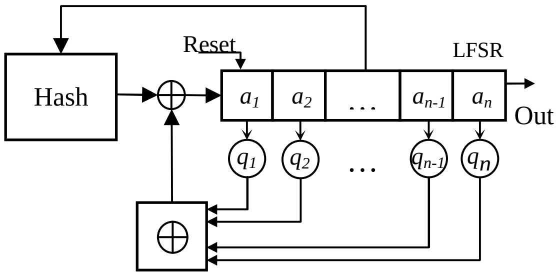

***Fig. 2. Block diagram of LSFR which length is n* [b]**

At each step the value of the hash function is calculated by the following formula:

$$Hash = (A.13 + 214748364).\mathrm{mod}99991 \tag{4}$$

where *A* is the current value of the shift register.

Then a modulo 2 addition performed and the result is placed at the least significant bit of shift register.

4. STATISTICAL TESTS

The proposed scheme for generating pseudo-random sequences (Fig. 2) is evaluated by statistical tests and is compared with the classic scheme (Fig. 1). The results are for the following feedback polynomial [9]:

$$F_1(x) = x^8 + x^4 + x^3 + x^2 + 1 \tag{5}$$

$$F_2(x) = x^{12} + x^6 + x^4 + 1 \tag{6}$$

$$F_3(x) = x^{13} + x^4 + x^3 + x + 1 \tag{7}$$

$$F_4(x) = x^{16} + x^{14} + x^{13} + x^{11} + 1 \tag{8}$$

5. STANDARD TEST FOR RANDOMNESS IN MATLAB ENVIRONMENT

The test is performed using MatLAB function [h,p]=runstest(x), with an argument tested sequence of length $M = 2^n - 1$. The test returns the logical value h = 1 if it rejects the null hypothesis H_0 and h = 0 if it cannot. If null hypothesis cannot be rejected, it means that the sequence is random. The value p is the probability for accepting H_0 at 5% significance level.

The results of the test are included in Tables 1, 2, 3 and 4 respectively for bit sequence [b] and converted to a decimal numbers.

The following conclusions can be made from the table:

By increasing the length of the generated pseudo-random sequence, the scheme containing hash function has better statistical estimates. It is visible that the law of distribution is close to uniform.

6. THE FREQUENCY (MONOBIT) TEST

The focus of the test is the proportion of zeroes and ones for the entire sequence. The purpose is to determine whether the number of ones and zeros in a sequence are approximately the same as would be expected for a truly random sequence. The test is performed under MatLAB environment, following the instructions in [5]. Estimates of the output sequences for the corresponding feedback polynomials are presented in Tables 1, 2, 3 and 4 and are labelled as FREQ HASH for scheme with the hash function and FREQ LFSR scheme without hash function.

Table 1: Estimation for polynomial $F_1(x) = x^8+x^4+x^3+x^2+1$

2^N	N	9	10	11	12	13	14	15	16	17	18	19	20	21
With hash	h	0	0	0	0	0	0	0	0	0	0	0	0	0
function [b]	p	0,965	0,926	0,878	0,888	0,991	0,981	0,969	0,972	0,998	0,995	0,992	0,993	0,999
Without hash	h	0	0	0	0	0	0	0	0	0	1	1	1	1
function [b]	p	1	1	0,982	0,888	0,85	0,689	0,488	0,317	0,156	-	-	-	-
With hash	h	0	0	1	1	1	1	1	1	1	1	1	1	1
function [10]	p	0,206	0,107	0,029	0,016	-	-	-	-	-	-	-	-	-
Without hash	h	0	0	0	0	0	0	0	0	0	0	0	0	0
function [10]	p	0,372	0,68	0,55	1	0,965	0,875	0,841	0,766	0,682	0,622	0,509	0,317	0,155
FREQ HASH	p	1	0,901	0,86	0,975	1	0,975	0,965	0,994	1	0,994	0,991	0,998	1
FREQ LFSR	p	1	1	0,965	0,876	0,724	0,639	0,466	0,317	0,157	0,046	-	-	-

Table 2: Estimation for polynomial $F_2(x)= x^{12}+x^6+x^4+1$

2^N	N	N	13	14	15	16	17	18	19	20	21
With hash	h	h	0	0	0	0	0	0	0	0	0
function [b]	p	p	0,936	1	0,866	0,852	0,688	0,551	0,397	0,236	0,087
Without hash	h	h	0	0	0	0	0	0	0	0	0
function [b]	p	p	1	1	1	0,991	0,967	0,927	0,882	0,823	0,731
With hash	h	h	0	0	0	0	0	0	0	0	1
function [10]	p	p	0,691	0,928	0,801	0,784	0,589	0,439	0,266	0,123	-
Without hash	h	h	0	0	0	0	0	0	0	0	0
function [10]	p	p	0,41	0,307	0,887	1	0,991	0,994	0,969	0,935	0,914
FREQ HASH	p	p	0,596	0,522	0,228	0,09	0,012	-	-	-	-
FREQ LFSR	p	p	1	1	1	0,975	0,934	0,894	0,866	0,81	0,724

Table 3: Estimation for polynomial $F_3(x)= x^{13}+x^4+x^3+x+1$

2^N	N	14	15	16	17	18	19	20	21
With hash	h	0	0	0	1	1	1	1	1
function [b]	p	0,2384	0,1874	0,0513	-	-	-	-	-
Without hash	h	0	0	0	0	0	0	0	0
function [b]	p	1	1	1	0,9933	0,9735	0,9482	0,9136	0,8688
With hash	h	0	0	0	0	0	0	0	0
function [10]	p	0,2737	0,439	0,4784	0,5688	0,5494	0,4717	0,3657	0,2245
Without hash	h	0	0	0	0	0	0	0	0
function [10]	p	0,303	0,3888	0,7646	1	1	0,9955	0,9968	0,9845
FREQ HASH	p	0,7546	0,5361	0,7665	0,6505	0,696	0,5768	0,4627	0,335
FREQ LFSR	p	1	1	1	0,9867	0,9626	0,9449	0,9082	0,8575

Table 4: Estimation for polynomial $F_4(x) = x^{16}+x^{14}+x^{13}+x^{11}+1$

2^N	N	17	18	19	20	21
With hash function [b]	h	0	0	0	0	1
	p	0,485	0,491	0,15	0,06	0,004
Without hash function [b]	h	0	0	0	0	0
	p	1	1	1	0,999	0,993
With hash function [10]	h	0	0	0	0	0
	p	0,886	0,487	0,328	0,1	0,085
Without hash function [10]	h	0	0	0	0	0
	p	0,699	0,579	0,297	1	1
FREQ HASH	p	0,536	0,507	0,27	0,132	0,026
FREQ LFSR	p	1	1	1	0,998	0,994

7. UNIFORM DISTRIBUTION TEST

Figure 3 and Figure 4 show the histograms and autocorrelation functions of the generator with and without hash function with a primitive polynomial in the feedback relation $F_4(x)$ (7). For the construction of the histograms every 16 bits are converted to decimal numbers, then the *hist(..)* function is used in MatLAB, where the number of non-overlapping intervals is 50.

From the figures it is obvious that the distribution of values is close to the uniform law of distribution. Autocorrelation functions are built to the same transformed output signals, as an normalization is done in advance.

Figures 3 and 4 show that autocorrelation functions of the signal from the generator with hashing have lower sidelobes compared with those of classical scheme, which in turn is an indicator of quality.

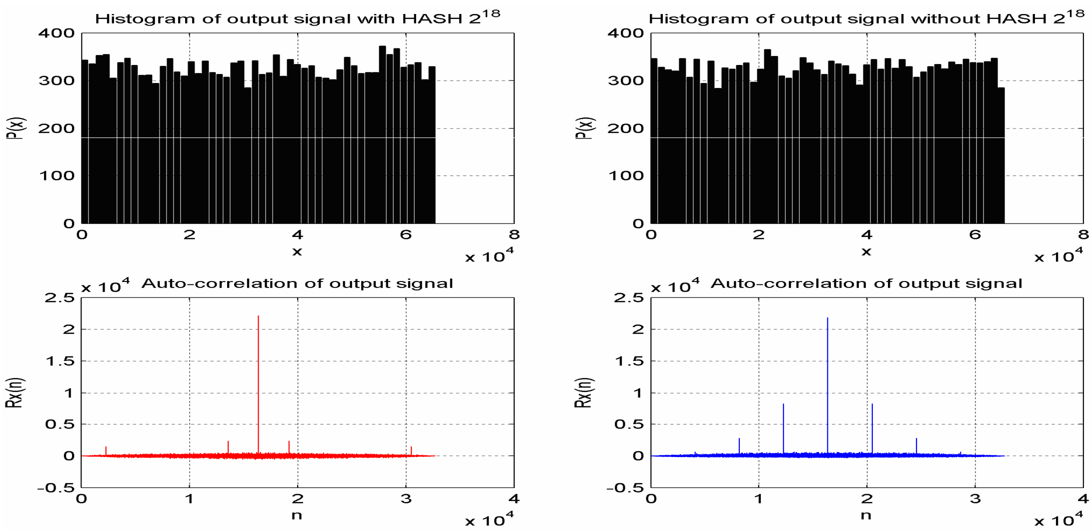

Fig. 3. Histogram and Autocorrelation function of PSG with polynom $F_4(x)$

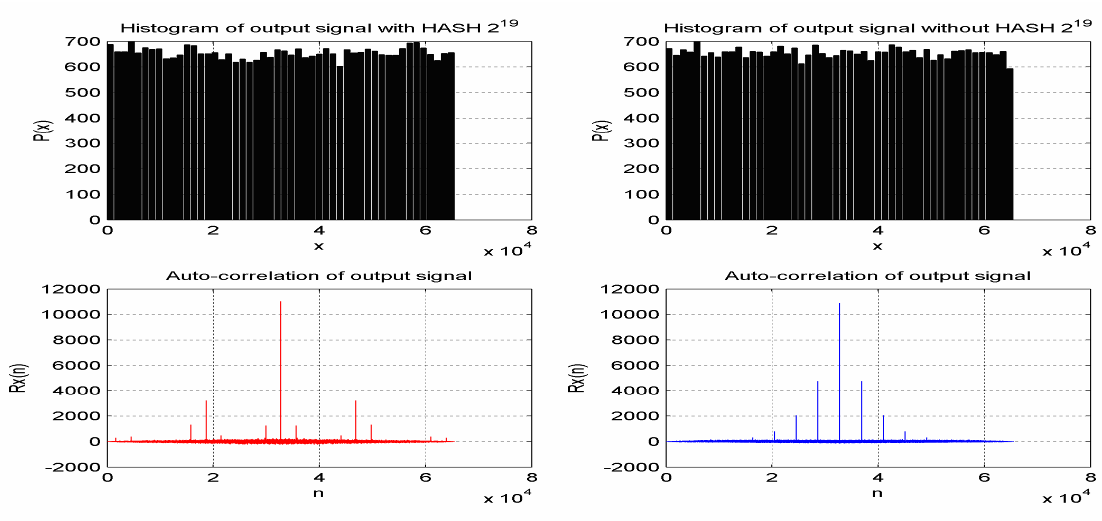

Fig. 4. Histogram and Autocorrelation function of PSG with polynom $F_4(x)$

8. HARDWARE REALIZATION

A prototype of the proposed generator of signal is implemented on microcontroller dsPIC33FJ128GP802 from Microchip, holding channel digital-to-analog converter (DAC). The specific 16-bit microcontroller combines specialized DSP core, multiple modules (timers, ADC, DAC) and flexible peripherals. The circuit diagram is shown in Figure 5.

The circuit allows frequency and phase modulation of a sinusoidal signal with a pseudorandom binary sequence. Figures 6 and 7 show 2-channel phase and frequency modulation of a sinusoidal signal with pseudo-random binary signal. The sequence is obtained in polynomial $F_1(x)$ (5).The two output signal have phase difference of 180°.

When using the second DAC of the dsPIC33FJ128GP802 and by shift the phase of the two channels with 90° it is possible to generate a quadrature phase-shift keying modulation. The power supply of the scheme is by bipolar voltage ± 5V, necessary for the operation of operational amplifiers and the microcontroller is powered by a linear stabilizer on 3.3V.

The scheme uses a built-in clock generator microcontroller, and if necessary, an external one can be used too, for greater frequency stability.

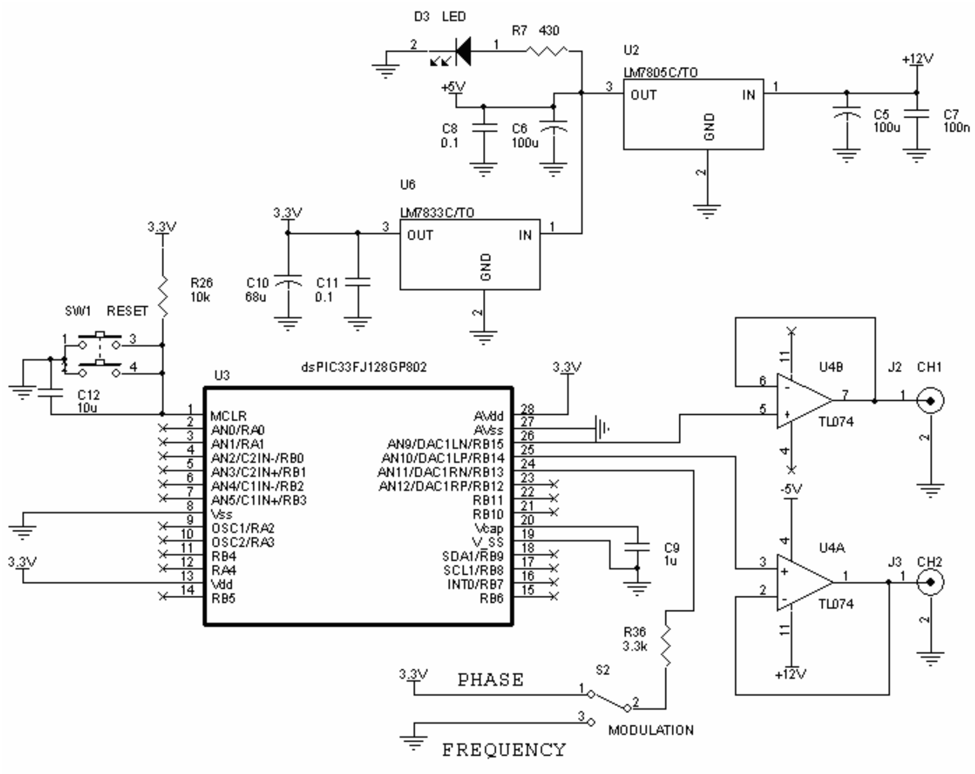

Fig. 5. Circuit diagram of the generator

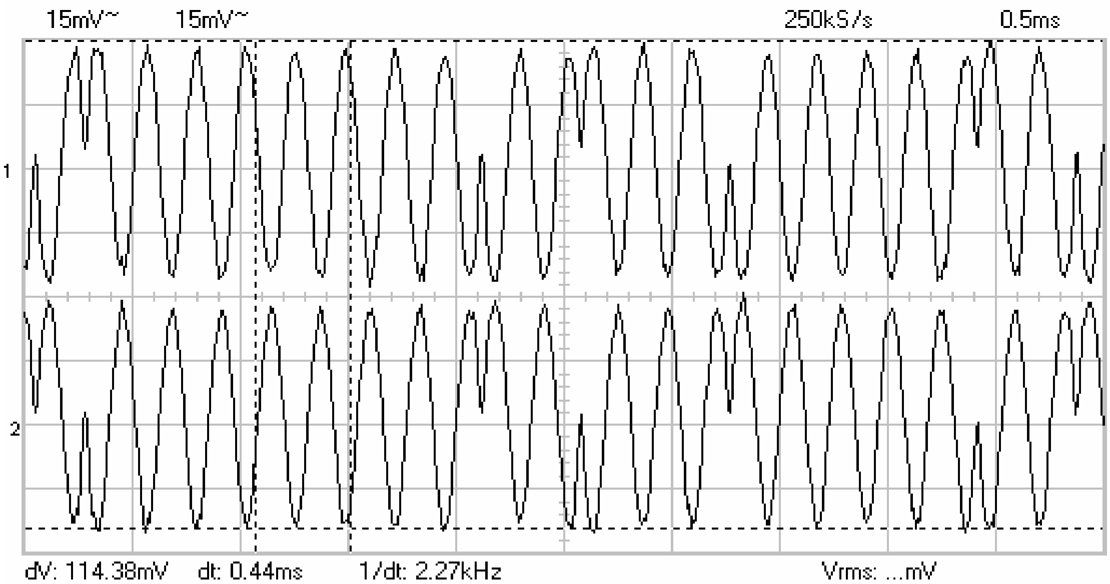

Fig. 6. Phase pseudo-random modulation

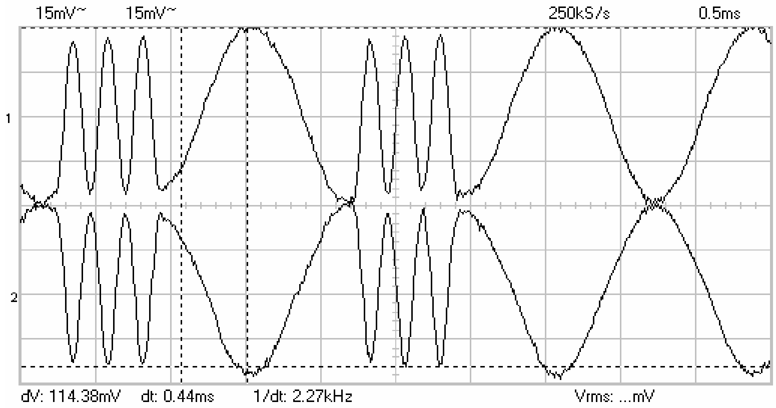

Fig. 7. Frequency pseudo-random modulation

9. CONCLUSIONS

The obtained experimental results allow us to claim that the proposed generator is better than the classical LFSR generators. It is noted that the results depend heavily on the rank of the shift register and type of primitive polynomial. Experiments were made with different values of the numbers in the hash function, in which it is found that the statistical parameters of the output sequence depend on them.

From the results presented in Tables 1, 2, 3 and 4 it is clearly shown that the polynomial of degree 8 gets the best results when compared with the rest of the polynomials , under the same values of the hash function. Furthermore this significantly increases the length of the output bit sequence, in which does not reject the statistical tests.

The above listed dependencies give us a reason for further study of the generator, looking for "good" polynomial and coefficients of the hash function.

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MODEL-BASED TORSIONAL VIBRATION OF MARINE INTERNAL COMBUSTION ENGINES Part 1

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The purpose of the present paper is to be a tutorial one, intended to show the model of torsional vibration of the high power marine engine shafting systems. Extension of the analytic method for a multi-dimensional system, modeling of typical marine propulsion plant, and results for some realistic examples are also presented.

***Keywords**:* Marine engines, torsional vibrations, mode superposition method

1. MATHEMATICS

Differential equation for torsional vibration calculation of *n*-degree-of-freedom mechanical system, in matrix form is as follows:

$$\mathrm{M}\ddot{\mathrm{X}}(\mathrm{t}) + \mathrm{C}\mathrm{X}(\mathrm{t}) + \mathrm{K}\mathrm{X}(\mathrm{t}) = \mathrm{F}(\mathrm{t}) \tag{1}$$

where: *X(t)* – vector of the twisting angles at the system nodes (solution of the equation); *M* – mass matrix; *C* – damping matrix; *K* – stiffness matrix; *F* – excitation torque vector.

If damping matrix is a liner combination of mass and stiffness matrix *C =αM + β K* **(**Rayleigh damping case), the matrix equation for *n*-degree-of-freedom mechanical system can be substituted by the system of *n* differential equations for one-degree-of-freedom oscillator:

$$\ddot{x}_i + 2\zeta_i\lambda_i\dot{x}_i + \lambda_i^2 x_i = Q_i(t), \mathrm{i} = 1, 2, 3, ... \tag{2}$$

where: x_i – *i*-th generalized coordinate; λ_i – *i*-th natural frequency; ζ_i – *i*-th mode damping ratio (modal damping); $Q_i(t)$ – *i*-th generalized force;

Final solution of torsional vibration problem in this case will be find according to the formula:

$$\Theta(x,t) = \sum_{i=1}^{n} x_i(t)V_i(x) \tag{3}$$

where: Θ(x, t) - twisting angles; xi (t) - solution of i-th equation; V (x) - i-th mode shape.

This approach is known as a mode superposition method. The simplification is permissible also where damping is not really the Rayleigh damping but is low enough. In such cases we can avoid the need to form a damping matrix based on the physical properties of individual structure elements. It is enough to know mode damping ratios ζ i
Torsional vibration calculation issues that will be discussed hereafter concern the second and the third structural mechanics problems: methods used to solve the torsional vibration equation and setting of propulsion system parameters (matrices' elements).

2. FREE VIBRATION CALCULATION ISSUES

The simplest way to check the propulsion system with fixed mass and stiffness parameters for resonance appearance is to perform calculation of a free non damped torsional vibration i.e. to solve the equation:

$$M\ddot{X}(t) + KX(t) = 0 \tag{4}$$

and build a resonance table or plot a Campbell diagram, like shown on Fig. 1.

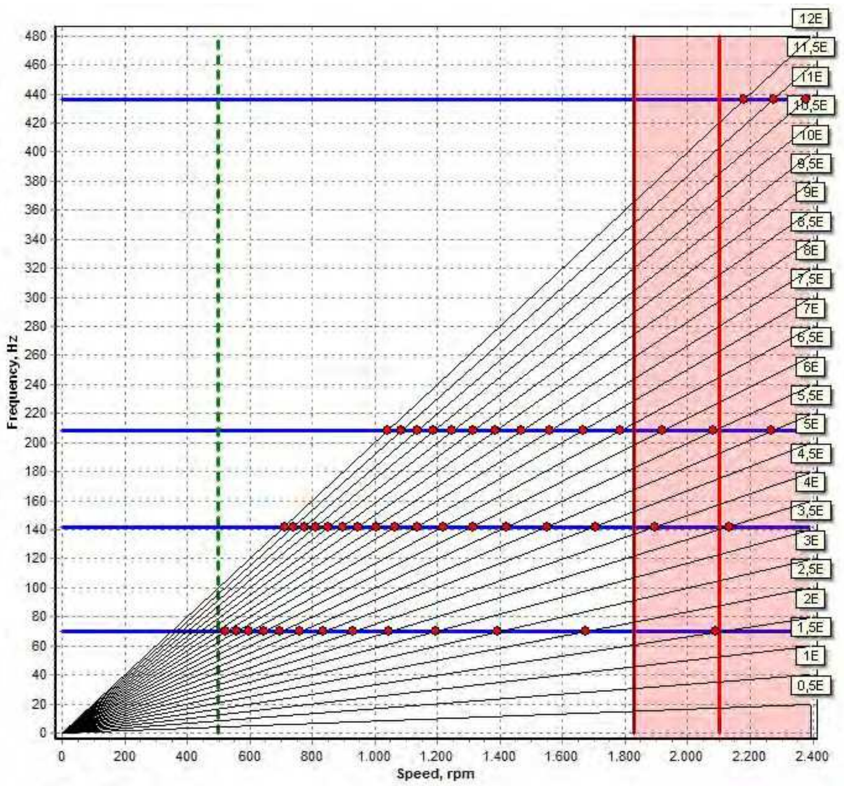

Fig. 1. Campbell diagram for generator set vibration

The red points show possible resonances i.e. the speeds where the harmonic excitation torque frequencies are equal to the natural torsional vibration frequencies. It does not mean that all resonances will happen but where the excitation energy of certain frequencies is great enough the resonances are inevitable. Thereby free vibration calculation results give an initial idea about the possible resonances in operating propulsion system.

Free torsional vibration calculation for system with fixed mass and stiffness parameters is a purely mathematical problem. Methods of non damped natural frequency calculation are well developed and not discussed in this presentation. The most widely used methods where introduced by M. Tolle and H. Holzer in the period from 1905 to 1921. The matrix methods, that are more suitable for computer based calculations, were developed later.

It should be pointed out that the accuracy of frequencies and mode shapes determination by these methods for the installations with a low damping is sufficient. When the damping is high, calculated non damped frequencies and mode shapes may be used for the reference only. The actual resonance speed and the calculated non damped resonance speed can differ significantly. It can be seen from the vibration stress diagram (Fig. 3) calculated for the propulsion train, equipped with viscose torsional vibration damper (Fig. 2).

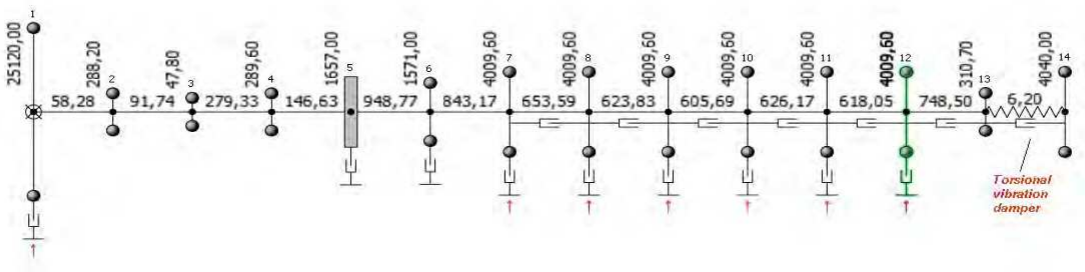

Fig. 2. Propulsion train with the torsional vibration damper

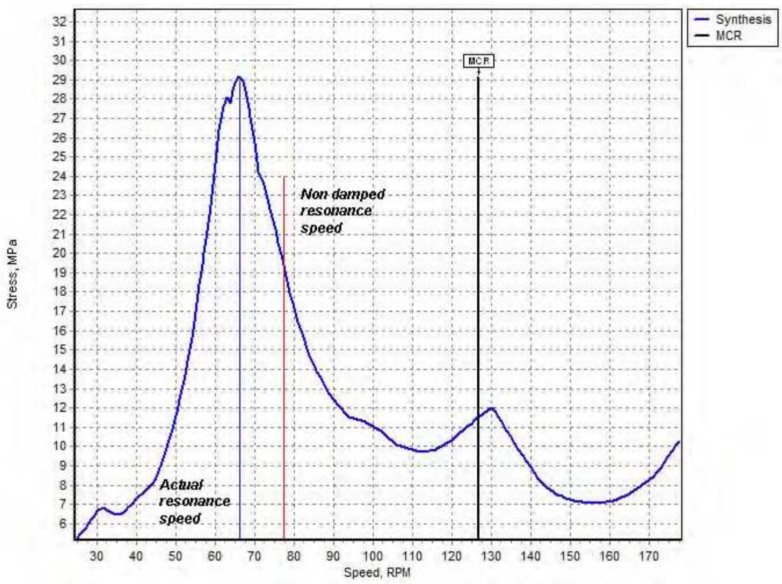

Fig. 3. Shift of the resonance speed for high damped system

If the installation comprises the element, dynamic stiffness of which depends on vibration frequency, as we have for Geislinger flexible coupling (Fig. 4) or on transmitted torque, the natural frequencies must be calculated for the whole range of operating speed.

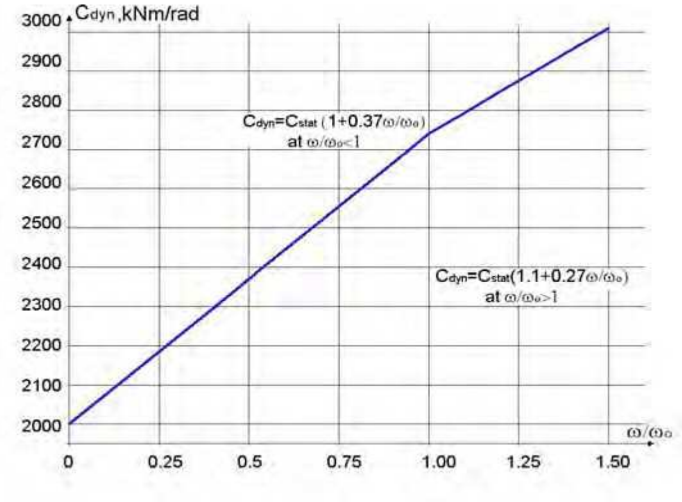

Fig. 4. Variable dynamic stiffness of the flexible coupling

In this connection DNV Rules for Classification of Ships recommended to calculate natural frequencies with at least the maximum and minimum values of flexible element stiffness. If the propulsion system comprises several frequency dependent flexible elements, combinatorial approach should be used. The torsional vibration problem becomes non linear if the dynamic stiffness depends on vibratory torque (Fig. 5) and natural frequency idea in this case is not applicable at all.

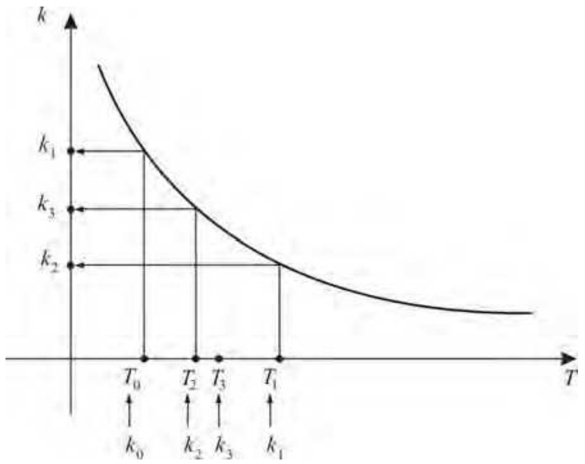

Fig. 5. Non linear dynamic stiffness of the flexible element

These circumstances bring down the importance of a free vibration calculation for realistic estimation of the resonance speeds of modern propulsion systems.

3. FORCED VIBRATION CALCULATION METHODS

The goal of forced torsional vibration calculation of a propulsion system is to satisfy the acceptance criteria formulated in Classification Societies Rules or in other regulations or standards.

Irrespective of what the regulation is used to check the acceptance criteria following parameters must be calculated:

- vibration angles at the nodes;
- vibration torque in the elements;
- vibration shear stresses in the elements;
- dissipated power in the flexible elements;
- gear hammering for geared propulsion systems.

There are two classes of methods for forced vibration calculation: time domain class and frequency domain class. Algorithm for selection of forced vibration calculation method is shown in Fig. 6.

Most universal method is the time domain method of direct numerical integration of torsional vibration equation. It may be used at any condition regardless of equation coefficients properties and excitation torque type.

To calculate propulsion shafting forced torsional vibration more often frequency domain methods are used: mode superposition method and full solution method. Both methods are applicable only if the excitation torque has a harmonic character. It should be noted that full solution method is always applicable, but the mode superposition may be applicable for low damped propulsion systems only.

The stress diagrams (Fig. 7 and Fig. 8) calculated for intermediate shaft of the system Fig. 7 shows how the mode superposition method results for high damped system differ from the results obtained with the full solution method.

The excitation torque produced by a diesel engine cylinder is periodic but non harmonic (Fig. 9). Torque period is equal 2π for two stroke engines and 4π for four stroke engines. For such excitation type frequency domain methods for forced vibration calculation of the propulsion systems driven by diesel engines cannot be applied directly.

Provided excitation torque expansion in a Fourier series is used

$$f_i(t) = \sum_{k=1}^{N} A_{ik} \sin(\omega_{ik} t + \psi_{ik}) \tag{5}$$

torsional vibration calculation can be performed in the frequency domain i.e. for each excitation order separately.

There are a lot of in house developed and commercially supplied software which implement all or some of above mentioned methods to calculate free and forced vibration of propulsion system.

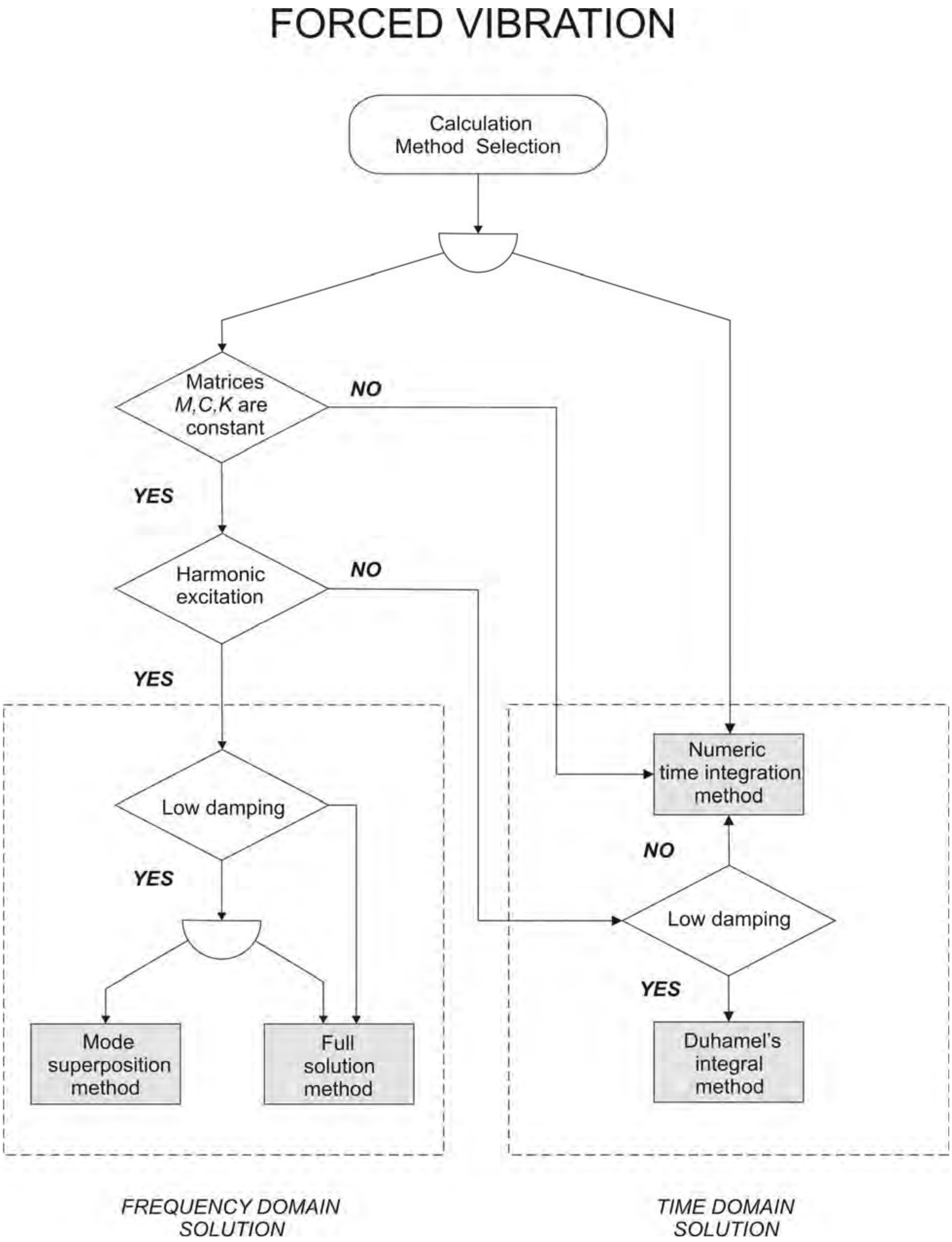

Fig. 6. Algorithm for selection of forced vibration calculation method

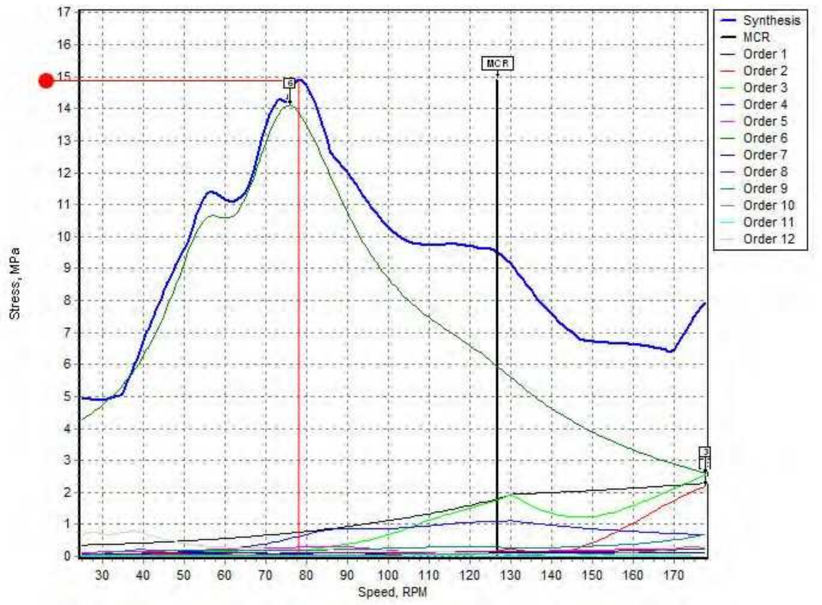

Fig. 7. Mode superpositios method result

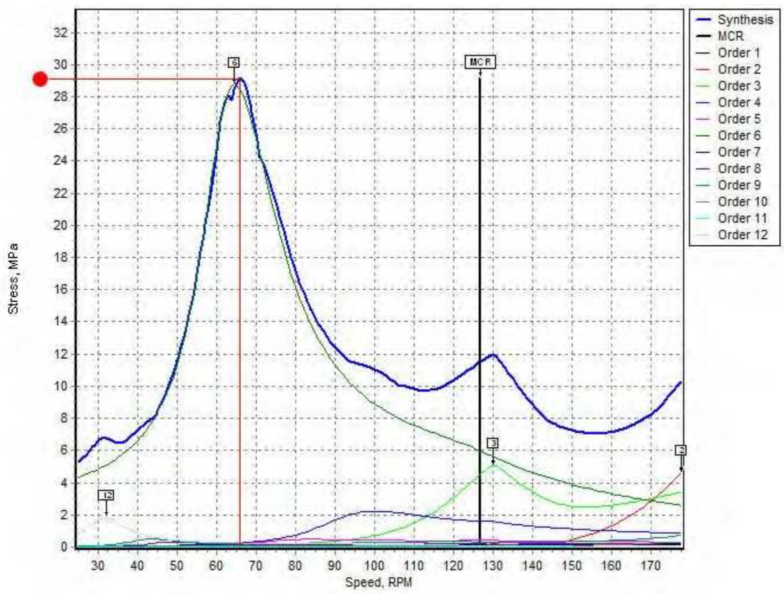

Fig. 8. Full solution method result

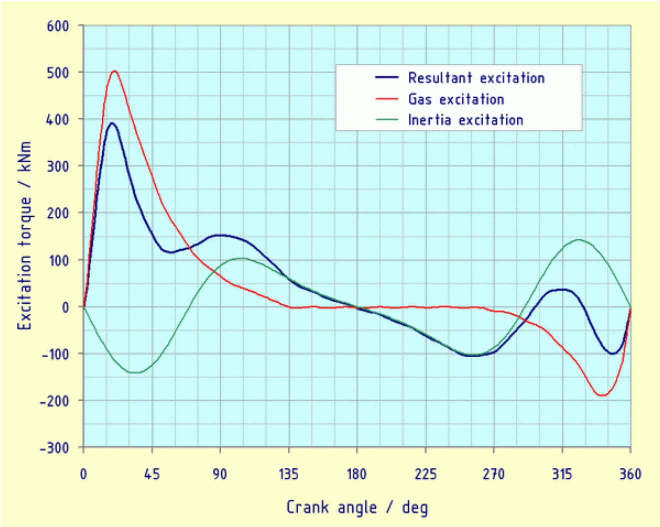

Fig. 9. The excitation torque of two stoke diesel engine cylinder

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MODEL-BASED TORSIONAL VIBRATION OF MARINE INTERNAL COMBUSTION ENGINES - Part 2

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The purpose of the present paper is to be a tutorial one, intended to show the model of torsional vibration of the high power marine engine shafting systems. Extension of the analytic method for a multi-dimensional system, modeling of typical marine propulsion plant, and results for some realistic examples are also presented.

Keywords: Marine engines, torsional vibrations

1. PROPULSION TRAIN MODELING ISSUES

A propulsion shaft line (Fig.1) is a continuous body consisting of cylindrical and conical shaft elements and may includes the elements such as diesel engine cranks, torsional vibration dampers and other equipment. Bearings do not influence a torsional vibration significantly and are therefore ignored in torsional vibration calculations.

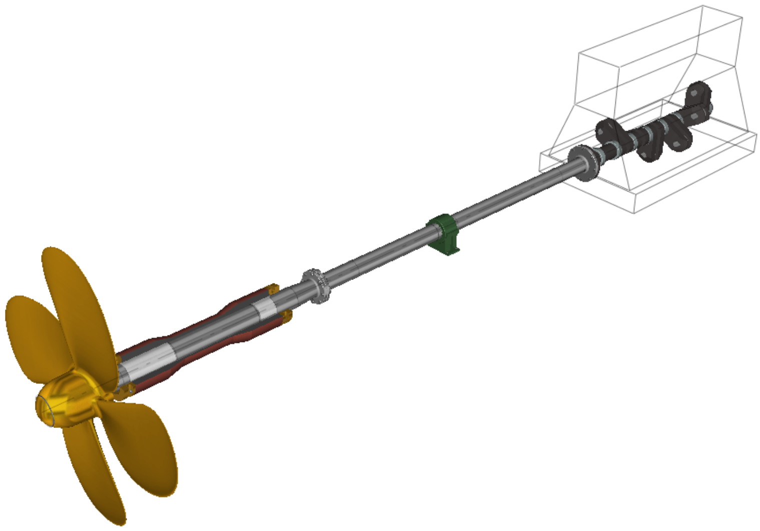


Fig. 1. Propulsion shafting of the directly driven propulsion plant

While a propulsion shaft line is a continuous body its torsional vibration calculation model usually is presented as a discrete system consisting of lumped masses connected by a weightless flexible elements, Fig. 2. Propeller shafts and intermediate shafts are long but in the mass elastic system each of them is presented as a single element.

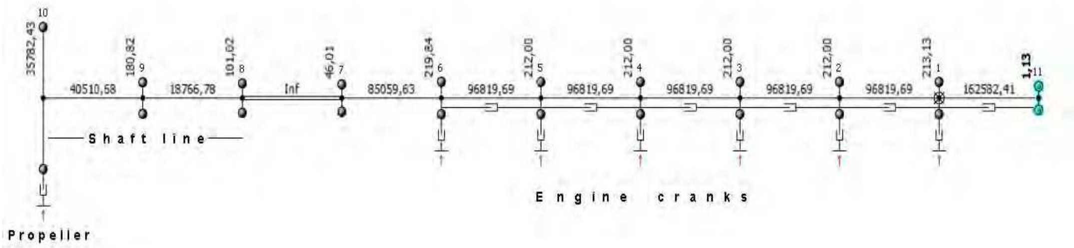


Fig. 2. Discrete mass-elastic system of propulsion shafting

Currently for the torsional vibration calculation computer programs are used and so simple representation of the continuous structure looks as a heritage from the of manual calculation times when a mass-elastic system with large number of lumped masses was practically impossible to calculate. But such an approach is valid, even today, when for torsional vibration calculation powerful tool such as the Finite Element Method is used.

Actually, for the simple shafts, the natural frequencies of torsional vibration depend heavily on the amount of discretization, especially the higher frequencies.

The influence of discretization remains considerable when the shaft has a propeller at the end, (Fig. 3). Propeller inertia to shaft inertia ratio (I_p/I_s) for most of ships is within the range 1 to 40. As can be seen from the picture, in order to have correct values of the first natural torsional vibration frequency, the shaft model must consist of minimum 5-6 elements. Higher natural frequencies will require more detailed discretization of the shaft.

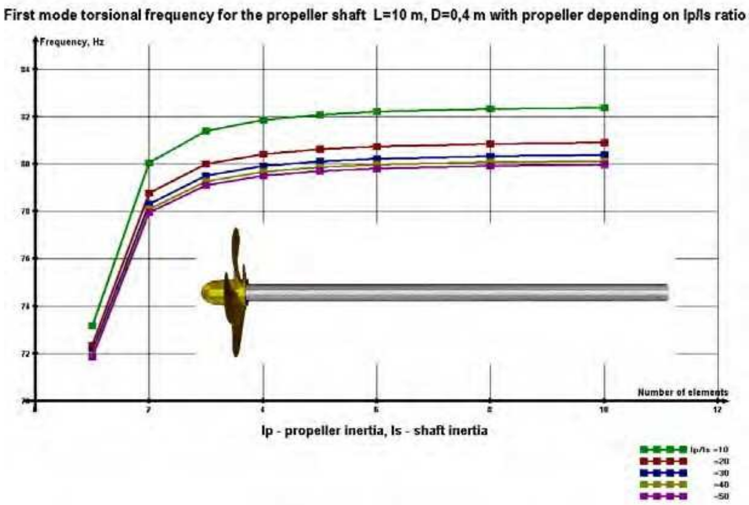


Fig***. 3. The 1-st natural frequency dependence on shaft discretization and propeller inertia***

The influence of discretization on natural frequencies of torsional vibration decreased considerably after the shaft is connected to the engine (Fig. 4.). For the highest frequencies the difference is not greater than 10 % (see Table 1.).

Fig. 4. Propulsion shaft line

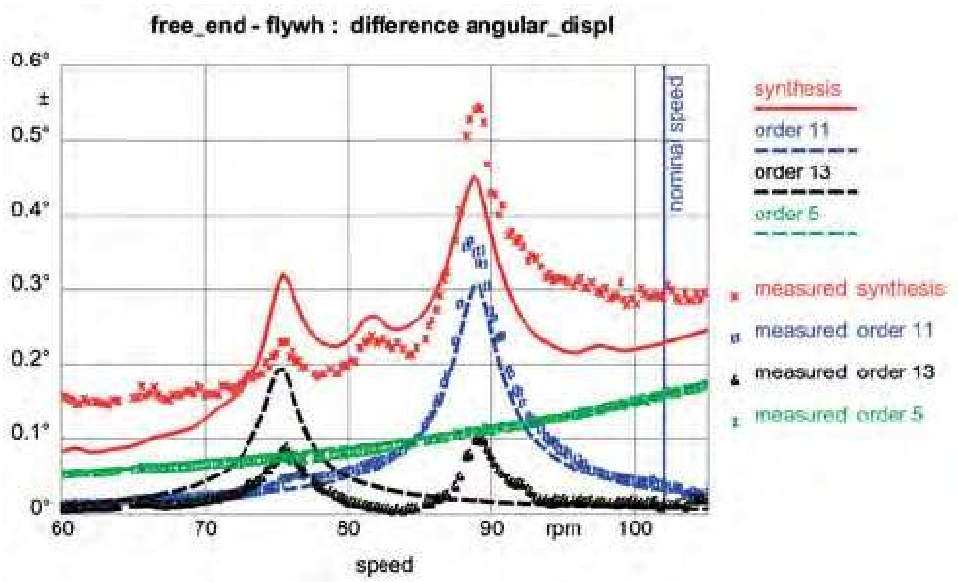
Table 1. Natural frequencies for *n*-element system

Natural Frequency	Number of elements			
	2	4	8	16
1	22,57	22,62	22,64	22,66
2	69,09	69,33	69,39	69,40
3	118,94	119,47	119,55	119,52
4	145,27	149,02	149,58	149,65
5	180,40	184,42	184,96	185,06
6	209,50	214,92	215,31	215,37
7	222,34	237,61	243,42	244,70

The uniqueness of a propulsion shaft line structure allows do not split propeller shafts and intermediate shafts on a short elements when the torsional vibration mass-elastic model is composed.

W. Schiffer [5] showed Draminsky's effect for 8RTA/RT-flex96C/CB diesel engine comparing measured and calculated stress using conventional and advanced method, with alternate inertia moment of the crank (Fig. 5-7).

As can be seen large variations in inertia torques gave prove of the secondary resonance in torsional vibrations, which cannot be explained by conventional theories incorporating only the mean values of the varying inertias. The secondary resonance can be extremely dangerous for the crankshafts.



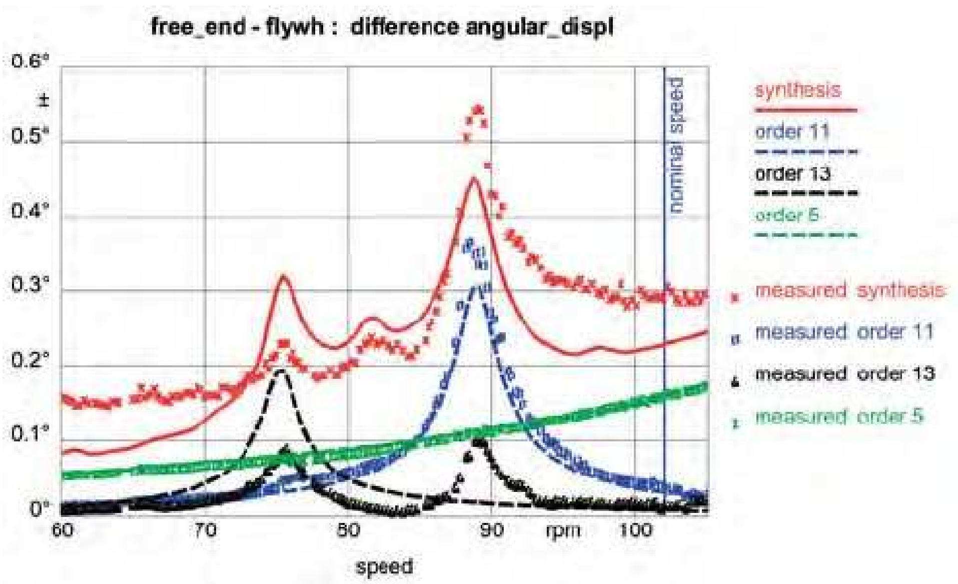


Fig. 5. Relative crankshaft angular displacement (constant inertia moment of the cranks)

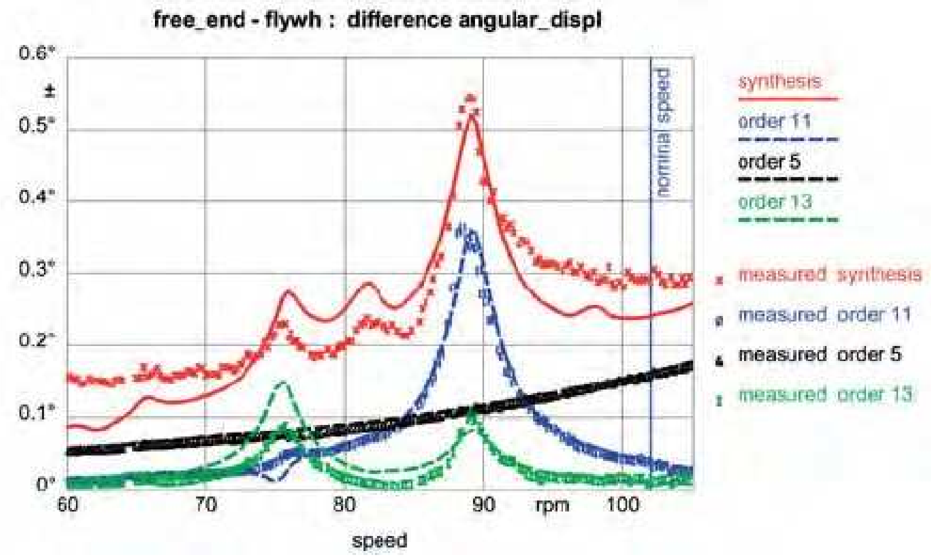


Fig. 6. Relative crankshaft angular displacement (alternate inertia moment of the cranks)

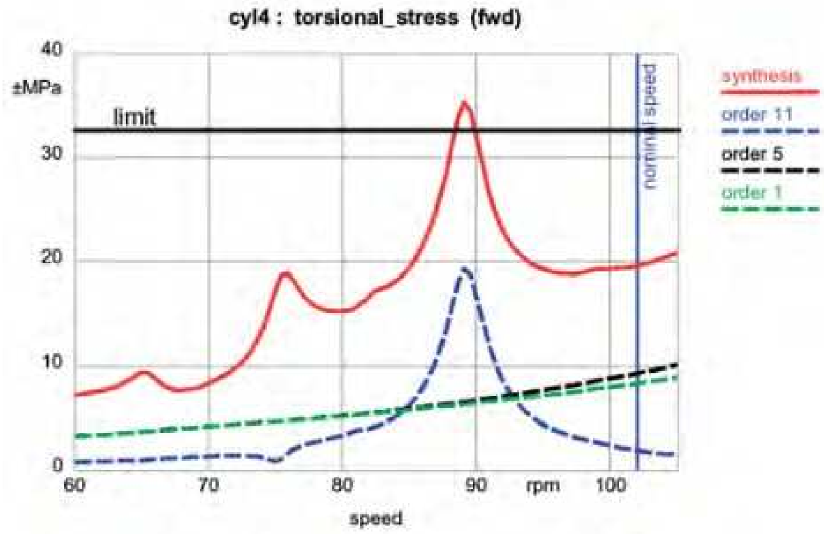


Fig. 7. Torsional stress calculated with alternate crank inertia moment

2. CONCLUSIONS

When propulsion shafting is considered, as it is mostly dynamically loaded, its dynamic behavior is the major factor influencing its overall reliability and efficiency. This means that shafting vibration behavior, especially torsional vibration behavior, is the most important factor influencing shafting design.

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RADAR IMAGE DESCRIPTION USING AUTOREGRESIVE AR(4) TIME SERIES AND HIGH ORDER SPECTRAL MOMENTS APPROACH

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This article presents an attempt for modeling and estimation of radar images of a ship (presented as a rough surface) using high order spectral moments and time series. Experiments with real images obtained by a costal surveillance radar are described. The results are estimated by using autoregressive models of fourth order. Experimental results with AR(2) and AR(4) have been compared and discussed.

Keywords*:* Radar image, spectral moments, AR(4), time series, estimation

1. INTRODUCTION

Some theoretical foundations and experimental results achieved by applying Autoregresive AR(2) models to a ship's radar image presented as a rough surface were described in [13]. This paper introduces results achieved by applying autoregressive time series models over two different types of merchant ships using models of order four.

2. AUTOREGRESSIVE MODEL AR(4) AND TIME SERIES

Using experimental data Z(X) a parameter identification is done by the least-square method on linear differential equations of fourth order:

$$\frac{d^4Z}{dX^4} + a_3.\frac{d^3Z}{dX^3} + a_2.\frac{d^2Z}{dX^2} + a_1.\frac{dZ}{dX} + a_0.Z = U(X) \qquad (1)$$

where U(X) is a random function, uncorrelated with Z(X), with normal law of distribution.
Both functions U(X) and Z(X) have zero mathematical expectacions and known variances. If the conditions for the differential equation are available, autocorrelation function of Z(X) satisfies the differential equation of the type:

$$\frac{d^4R_Z}{dX^4} + a_3.\frac{d^3R_Z}{dX^3} + a_2.\frac{d^2R_Z}{dX^2} + a_1.\frac{dR_Z}{dX} + a_0.R_Z = 0 \qquad (2)$$

where Rz(x) is autocorrelation function of Z(X),
x is independent variable expressing the offset (lag) in the direction X [5].

In particular, this equation is true when the lag x = 0. Then using the relationship between the spectral moments and the values of the derivatives of the autocorrelation function at x = 0, which is given by:

$$m_k = (j)^k \cdot \frac{d^k R_z}{dx^k}\Big|x = 0 \tag{3}$$

where j is imaginary unit, the differential equation is transformed to the following form:

$$m_4 - j.a_3.m_3 - a_2.m_2 + j.a_1.m_1 + a_0.m_0 = 0 \tag{4}$$

Since the Z(X) is a real function the spectral density appears as an even function of the frequency and equation (4) is reduced to:

$$m_4 - a_2.m_2 + a_0.m_0 = 0 \tag{5}$$

According to the results described in [7], expressions for m_2 and m_4 are:

$$m_2 = m_0 \cdot \frac{a_0.a_3}{a_2.a_3 - a_1} \tag{6}$$

$$m_4 = m_2 \cdot \frac{a_3}{a_1} \tag{7}$$

where m_0 is the estimation of the empirical variance of Z(X).

These expressions allow to avoid the Fourier Transform when survey the topography of a surface, and instead to apply computational algorithms to identify the stochastic differential equation. This will allow to provide independent estimations of spectral moments that are necessary to specify statistical geometrical properties of the surface.

3. EXPERIMENTAL RESULTS

Two types of ships have been studied – a general cargo ship and a ferry-boat. Figures 1, 2, 3 and 4 show the objects of study and their radar images presented as rough surfaces.

Figure 1. General cargo ship

Figure 2. Ferry-boat

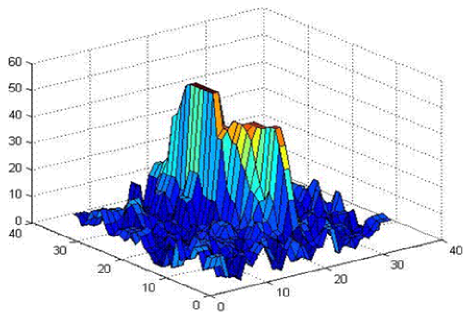

Figure 3. Reflecting surfaces of the cargo ship

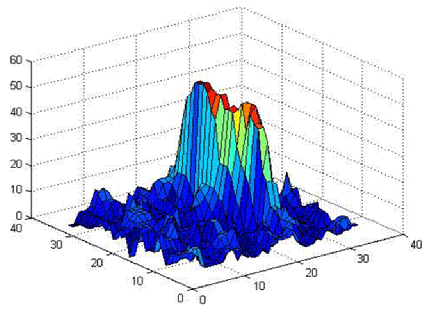

Figure 4. Reflecting surfaces of the ferry

The selected objects have specific superstructures and deck mechanisms dispositions, that can be detected in their radar surfaces. After applying mathematical tools described in [13], the obtained results are given in Tables 1 and 2.

Table 1: Results for the general cargo ship

AR(2) parameters		
tix0	0	
tix45	0.7854	
tix90	1.5708	
Fi_Zx0	**Fi_Zx45**	**Fi_Zx90**
1.0000	1.000	1.0000
-1.2595	-1.2952	-1.4382
0.4233	0.5048	0.4598
Mu_0	-0.4299 -0.4299	
Mu_45	-0.3418 -0.3418	
Mu_90	-0.0425 -0.7344	
a0	1.0000 0.8597 0.2493	
a45	1.0000 0.6836 0.2965	
a90	1.0000 0.7769 0.0312	
m2	49.6486 48.1287 3.2669	
M2	52.9156	
delta2	-307.4326	

Table 2: Results for the ferry

AR(2) parameters		
tix0	0	
tix45	0.7854	
tix90	1.5708	
Fi_Zx0	**Fi_Zx45**	**Fi_Zx90**
1.0000	1.0000	1.0000
-1.4519	-1.1198	-1.5668
0.5792	0.2755	0.5800
Mu_0	-0.2731 -0.2731	
Mu_45	-0.2813 -1.0079	
Mu_90	-0.0333 -0.5114	
a0	1.0000 0.5462 0.1675	
a45	1.0000 1.2892 0.2835	
a90	1.0000 0.5448 0.0170	
m2	22.2956 22.5622 4.2345	
M2	26.5300	
delta2	7.9712	

The parameters values shown in Tables 1 and 2 as well as the results published in [13] allow to make the following conclusions:

- The table shows that the slopes of cuts profile (tix) are the same, which means that the surrounding surface is uniform;
- The coefficients of the discrete model (Fi_Z) are different for each of the models having different values in each slice;
- The dispersion of two-dimensional angular factor M2 differs. This indicates that the surface contains sharp and scattered peaks;
- invariant of zero order (m2) characterizes the level of inequality. These results show that reflecting surfaces of marine vessels are not isotropic.

It is also obvious that the coefficients of autoregressive models for some of the sections are not consistent. Due to this fact a database should be made for various ships with their reflected cross sections at different angles of observation and they can be used for identification of marine vessels or to make models of higher order.

4. MODELLING THE REFLECTIVE SURFACE OF THE SHIP USING AUTOREGRESSIVE MODEL OF FOURTH ORDER AR(4)

Using theoretical apparatus presented in [13] a model AR (4) for general cargo ship has been made. The experimental results are shown in Table 3. These results can be used to draw the following conclusions:

- the roots of the characteristic equation show that the specimens are stationary samples;
- the values of the AR (4) are in the range, i.e the estimates of coefficients are consistent [By];
- invariant M4 and H4 of models have smaller values. This shows that there is no sharp variation in the structure of the ship, i.e. the superstructure of the ships does not have sharp edges;
- The small value of G in the model is interpreted as presence of large reflecting areas on the surface of the object.

Table 3. Experimental results for the general cargo ship

					AR(4) parameters
Mu_0	-0.0046+0.0006i	a63	1.0000	m4	0.0117e-004
	-0.0046-0.0006i		0.0374		0.0133e-004
	-0.0313+0.0316i		0.0024		0.1085e-004
	-0.0313-0.0316i		0.0000		0.0045e-004
Mu_45	-0.0034		0.0000		0.0137e-004
	-0.0102	a90	1.0000	m40	1.1791e-006
	-0.0328		0.0413	m31	-1.0348e-005
	-0.0681		0.0056	m22	6.3075e-007
Mu_63	-0.0127+ 0.0441i		0.0000	m13	1.0328e-005
	-0.0127-0.0441i		0.0000	m04	4.5207e-007
	-0.0059+0.0051i	a135	1.0000	M4	2.8927e-006
	-0.0059-0.0051i		0.0720	H	1.4308e-010
Mu_90	-0.0159+0.0714i		0.0031	G	0.1809e-005
	-0.0159-0.0714i		0.0000		-0.0020e-005
	-0.0003		0.0000		-0.0020e-005
	-0.0091	m0_0	2.2551e+002		0.1082e-005
Mu_135	-0.0017	m0_45	1.9215e+002	delta4	-3.0894e-016
	-0.0111	m0_63	2.0656e+002	k	0.0306
	-0.0296+0.0381i	m0_90	1.0342e+002	v	0.0843e-004
	-0.0296-0.0381i	m0_135	1.8652e+002		0.0910e-004
a0	1.0000	m2	0.0042		0.3767e-004
	0.0720		0.0044		0.1324e-004
	0.0025		0.0152	alpha	0.5268e+005
	0.0000		0.0003		0.4286e+005
	0.0000		0.0031		2.8143e+005
a45	1.0000	m4_0	1.1791e-006		0.5867e+005
	0.1146	m4_45	1.3331e-006	beta	-0.2084
	0.0036	m4_63	1.0850e-005	Hd	1.4308e-010
	0.0000	m4_90	4.5207e-007	Gd	1.9593e-012
	0.0000	m4_135	1.3747e-006		

5. CONCLUSIONS

The obtained experimental results show that the values of the last two coefficient of autoregressive model of fourth order for each of the sections have very small values and can be ignored in practice. Therefore it can be assumed that the description of the reflecting surface of the ships with autoregression models of order two is better than description by fourth order models since they contain fewer coefficients.

The work on this subject can be extended as follows:

1. Autoregressive models of high-order can be obtained by using experimental data.

2. If the theorems from [3, 9] will be applied to experimental data, low-order ARMA could be obtained. These low-order models may be useful to perform quick identification of radar targets of observation.

3. The approach described in this paper in combination with the method presented in [12] can easily be modified to allow building a system for traffic monitoring.

6. ACKNOWLEDGEMENT

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TEACHING MARITIME ENGLISH: WRITING GLOSSARIES IN EDUCATIONAL PURPOSES

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The paper suggests the analysis of what a glossary is and how glossaries can be used in the process of teaching/learning materials development. A glossary is considered to be a form of a dictionary. Its various formats and purposes may be of great help when planning everyday practical language or specialist teachers' activities including assessment sessions in case if the knowledge of a term and its definition are required. The description is supported by the samples used in work with Marine Engineers.

***Keywords**:* Maritime English, Marine Engineers, a glossary, practical use

1. INTRODUCTION

Understood as a collection of glosses, borrowed from Greek "glossarion", diminutive of "glossa" - "obsolete or foreign word", the word "glossary" came into English late in 14 century from Latin "glossarium". Obsolete or foreign words are the words which require explanation, thus later, the noun "gloss" came into use as the word inserted as an explanation, 1540s. Both glossology (since 1716) and glottology (since 1841) have been used in the sense "science of language."

Glossary is used to define terms relevant to the subject being covered. In most cases glossary is a list at the back of a book, explaining or defining difficult or unusual words and expressions used in the text. For readers, a glossary basically saves time to look them all up in a dictionary. Usually the glossary has only a few words in it which are commonly unknown but most words in the book are put into a glossary at the back. According to technical writers, a glossary, also known as a vocabulary or clavis ("a key, a glossary") is an alphabetical list of terms in a particular domain of knowledge with the definitions for those terms. Traditionally, a glossary appears at the end of a book and includes terms within that book that are either newly introduced, uncommon, or specialised. A bilingual glossary is a list of terms in one language defined in a second language or glossed by synonyms (or at least near-synonyms) in another language. In a general sense, a glossary contains explanations of concepts relevant to a certain field of study or action. In this sense, the term is related to a notion. A core glossary is a simple glossary or defining dictionary that enables definition of other concepts, especially for newcomers to a language or field of study. It contains a small working vocabulary and definitions for important or frequently encountered concepts, usually including idioms or metaphors useful in a culture. As defined by Richard Nordquist, a glossary is an alphabetised list of specialised terms with their definitions. A glossary is generally located after the conclusion in a report or proposal. (Nordquist, 2013).

The discussions of glossaries arrangement techniques is usually performed within the frameworks of technical writing and technical communication. "Because you will have numerous readers with multiple levels of expertise, you must be concerned about your use of high-tech language (abbreviations, acronyms, and terms). Although some of your readers will understand your terminology, others won't. However, if you define your terms each time you use them, two problems will occur: you will insult high-tech readers, and you will delay your audience as they read your text. To avoid these pitfalls, use a glossary." (Gerson Sh., 2006) Sometimes the location of a glossary changes: it’s possible to use a glossary if your report contains more than five or six technical terms that may not be understood by all audience members. If fewer than five terms need defining, it’s better to place them in the report introduction as working definitions, or use footnote definitions. In case of a separate glossary, it’s necessary to announce its location (Lannon, Gurak, 2006).

Students often use glossaries as study tools, because they quickly cover a wide range of concepts with clear, concise definitions. In a textbook with a glossary that accompanies each chapter, it can help to read the terms first to get a basic review of the concepts that will be covered, and then to read the chapter with the definitions fresh in the mind. A glossary can also be used as a building block for flashcards, as it highlights concepts that may turn up on a final. A glossary can also be a useful tool for someone exploring something new, whether it is computers or economics. For example, someone who is not very familiar with the Internet could benefit from reading definitions of the basic terms and issues. Glossaries are also an important part of software manuals, as they provide clear, in-context definitions for the material that is being covered. Since words sometimes have multiple meanings in the English language, such a glossary can be extremely useful because it will eliminate confusion. In books that use words and terms in foreign languages, a separate foreign language glossary may be included so that the reader can quickly look up definitions. Books with a lot of technical material like publications in sciences may also include definitions, and some glossaries may be quite technical themselves, since they are aimed at advanced users. Most typically, the list is arranged in alphabetical order, making it easy to use. (What’s glossary?, 2013)

Some authors emphasize on the use of glossaries in technical literature. For technical texts you use a glossary to quickly find the definition of a technical term. You will commonly find a glossary in the appendix of many text books, people often use a glossary to better understand the material of the book that they are reading. When you come across an unknown technical word that stops you from understanding the material, the glossary should provide a definition. (Bellis, 2013)

2. GLOSSARIES FOR MARINE ENGINEERS

An alphabetized list of engineering terms explained with the help of definitions serves as the means of creating teaching/learning materials used to:

-represent the scope of concepts/facts/personalities studied;
-collect the basic terms used in some particular field;
-explain the most difficult or unknown terms or facts;
-comment historical dates or statistical data;
-prepare terminological units for an exercise: *Match the term and its definition*.
-have access to short descriptions for quick revision;
-explain abbreviations and acronyms.

The following glossaries are suggested to demonstrate different purposes in the classroom activities:

2.1. Consolidation of materials

Turbo-

Etymology: turbo- formed c.1900 from turbine; influenced by Latin turbo "spinning top; "turbot (n.) "large flat fish," c.1300, from Old French turbut (12c.). But OED says of uncertain origin and speculates on a connection to Latin turbo "spinning top. "turbine (n.) 1838, from French turbine, from Latin turbinem (nom. turbo) "spinning top, eddy, whirlwind," related to turba "turmoil, crowd". Originally applied to a wheel spinning on a vertical axis, driven by falling water. Turbo in reference to gas turbine engines is attested from 1904. Turbocharger is from 1934. Aeronautic turboprop is attested from 1945, with second element short for propeller.

turbine, n (From Latin turbo, "whirl, whirling thing.") - A form of engine in which all driving parts rotate. There are various types in marine use. The working principle of a turbine is to efficiently convert the kinetic energy of a fluid, into torque (and therefore angular kinetic energy). The fluid is generally either liquid water under pressure, or steam under pressure, or in the case of an airplane or gas turbine engine, air and combustion gasses. The fluid impinges on the blades of the turbine, imparting energy to rotate the blades.

turbo-, prefix (of, relating to, or driven by a turbine). Formed c.1900 from turbine, influenced by L. turbo "spinning top.

turboalternator, n - (electricity) An alternator, such as a synchronous generator, which is driven by a steam turbine.

turboblower, n - (mechanical engineering) A centrifugal or axial-flow compressor.

turbocharger, n - a centrifugal compressor which boosts the intake pressure of an internal-combustion engine, driven by an exhaust-gas turbine fitted to the engine's exhaust manifold. **Marine turbocharger.** A form of super-charger, the turbocharger increases the density of air entering the engine to create more power. A turbocharger has the compressor powered by a turbine, driven by the engine's own exhaust gases.

turbocompressor, n - 1) The main unit of a gas-turbine jet engine, consisting of a compressor and an aircraft gas turbine that are mechanically coupled. Turbocompressors are sometimes used for the supercharging of piston engines; in this case the engine exhaust gases expand in the turbine, and the turbine rotates the compressor, which increases the pressure of the air supplied to the cylinders.

(2) A dynamic-type (centrifugal or axial-flow) compressor used for the compression and injection of gases. Such a compressor is more efficient than a reciprocating compressor and eliminates pressure surges in the injected gas.

turbogenerator, n electric generator or dynamo which is combined on one frame with a turbomotor, by which it is driven. (Engineering / Electrical Engineering) a large electrical generator driven by a steam turbine/

turbofan , n - 1. A turbojet engine in which a fan supplements the total thrust by forcing air directly into the hot turbine exhaust. 2. An aircraft in which a turbofan is used.

turbomachinery, n - Turbomachinery, in mechanical engineering, describes machines that transfer energy between a rotor and a fluid, including both turbines and compressors. While a turbine transfers energy from a fluid to a rotor, a compressor transfers energy from a rotor to a fluid. The two types of machines are governed by the same basic relationships including Newton's second Law of Motion and Euler's energy equation for compressible fluids. Centrifugal pumps are also **turbomachines** that transfer energy from a rotor to a fluid, usually a liquid, while turbines and compressors usually work with a gas. In general, two kinds of turbomachines are encountered in practice. These are open and closed turbomachines. Open machines such as propellers, windmills, and unshrouded fans act on an infinite extent of fluid, whereas, closed machines operate on a finite quantity of fluid as it passes through a housing or casing. Turbomachines are also categorized according to the type of flow. When the flow is parallel to the axis of rotation, they are called axial flow machines, and when flow is perpendicular to the axis of rotation, they are referred to as radial (or centrifugal) flow machines. There is also a third category, called mixed flow machines, where both radial and axial flow velocity components are present. Turbomachines may be further classified into two additional categories: those that absorb energy to increase the fluid pressure, i.e. pumps, fans, and compressors, and those that produce energy such as turbines by expanding flow to lower pressures. Of particular interest are applications which contain pumps, fans, compressors and turbines.

turbopropeller, n - A turbojet engine used to drive an external propeller.

turbopump, n - A turbopump is a gas turbine that comprises basically two main components: a rotodynamic pump and a driving turbine, usually both mounted on the same shaft, or sometimes geared together. The purpose of a turbopump is to produce a high pressure fluid for feeding a combustion chamber or other use. An axial turbopump designed and built for the M-1 rocket engine. A turbopump can comprise one of two types of pumps: centrifugal pump, where the pumping is done by throwing fluid outward at high speed; or axial flow pump, where alternating rotating and static blades progressively raise the pressure of a fluid.

2.2. Revision of material: Types of pumps

1. ***Centrifugal Pumps****:* True centrifugal pumps were not developed until the late 1600's, when Denis Papin, a French born inventor, made one with straight vanes. The curved vane was introduced by British inventor John G. Appold in 1851. Centrifugal pumps are inexpensive and can handle large amounts of fluid. They are widely used in chemical processing plants and oil refineries. There are several kinds of centrifugal pumps including radial-flow, mixed-flow, and axial flow.
2. ***Electromagnetic Pumps:*** These pumps are chiefly used to move liquid sodium and liquid potassium, which serve as coolants in nuclear reactors. They consist of electrical conductors and magnetized pipes. These conductors send current through the fluid. The fluid is then moved by the magnetic attraction and repulsion between the fluid's magnetic field and the magnetic field of the pipes.
3. ***Jet Pumps:*** They operate on the principle that high-velocity fluid will carry along any other fluid it passes through. Most jet pumps need a jet of steam or water through the fluid that needs to be moved. The jet carries the fluid with it directly into the outlet pipe and, at the same time, creates a vacuum that draws more fluid into the pump. The amount of fluid that is carried out of most jet pumps is several times the amount of fluid that is in the jet itself. Jet pumps can be used to raise water from wells that are deeper than 200 feet. They are also used to create a vacuum in an enclosed area; these are referred to as high-vacuum diffusion pumps.
4. ***Screw Pumps:*** These pumps are also known as positive-displacement pumps. It is also probably the world's oldest type of pump. Recently, it has become accepted in the United States for general use in pumping wastewater. It was based on the Archimedes screw principle that has a revolving shaft fitted with one, two, or three helical blades to rotate in an inclined trough and push the wastewater up the trough. This type of pump has two very evident advantages over the afore-mentioned centrifugal pumps, (1) it can pump large solids without clumping, (2) it operates at a constant speed over a wide range of flows with good

efficiencies. The photo to the left is of a screw pump from the Blacksburg Wastewater Treatment Plant.

5. ***Other Pumps*****:** Among the other types of pumps are axial-flow, rotary, and reciprocating pumps. Axial-flow pumps use a motor to direct fluid along a path that is parallel to the pump's axis. This is a straight-line path for the fluid from its entrance at the inlet pipe through the pump to the outlet pipe. These types of pumps are most often used as compressors in turbojet engines. There are several types of rotary pumps in use today. They are the most widely used positive displacement pumps. They are used to pump such viscous liquids as motor oil, syrup, and paint. There are three main types of rotary pumps including: (1) gear pumps, (2) lobe pumps, (3) sliding vane pumps. Reciprocating pumps are among the oldest types of pumps used. They consist of a piston that moves back and forth within a cylinder. Common reciprocating pumps are lift pumps, force pumps, and bicycle tire pumps. Lift pumps are used to draw water from wells. The outlet valve is on a piston, which moves up and down in the pump's cylinder. The inlet valve is at the closed end of the cylinder.

2.3. Revision or consolidation of material: Basic electrical terminology

AC and DC - abbreviations for alternating current and direct current respectively.
Amp (Ampere) **-** the unit of intensity of electrical current.
Box - an enclosure designed to provide access to the electrical wiring between ungrounded conductors is either 0 or 10 degrees. **Circuit** - a complete path from the energy source through conducting bodies and back to the energy source.
Circuit Breaker - a device designed to open and close.
Conductor - a substance or body capable of transmitting electricity.
Device - a unit of an electrical system that is intended to carry but not utilize electricity.
Equipment - a general term including material, fittings, devices, alliances, fixtures, apparatus.
Fuse - an over current protective device.
Ground - a conducting connection between an electrical circuit or equipment and the earth.
Nominal Voltage - the value assigned to a circuit (e.g. 120 volts, 240 volts, 480 volts). The actual voltage of the circuit can vary.
Ohm - the unit of electrical resistance**.**
Single Phase **-** a system of alternating current power where the phase relationship system.
Three Phase - a system of alternating current power where the phase relationship between ungrounded conductors is either 0 or 120 degrees.**Transformer** – an apparatus for converting an alternating electrical current**.**
Volt **-** the unit of electromotive force.
Watt **-** the unit of power or rate of work.

2.4. Consolidation of basic terminology: Diesel engine glossary

BDC **-** bottom dead center.
Bore – refers to diameter of engine cylinder.
Brake horse power
- refers to the amount of usable power delivered by the engine to the crankshaft.

Clearance volume
– volume remaining in the cylinder when piston is at TDC.

Compression ratio
- total volume / clearance volume.

Degree of crankshaft rotation
– because the piston is connected to the crankshaft, any location of the piston corresponds directly to a specific number of degrees of crankshaft rotation.

Engine displacement
–refers to the total volume displaced by the pistons during one stroke.

Firing order
– refers to in order in which each of the cylinder in a multi-cylinder engine fires.

Horse power
– power is amount of work done per unit time or the rate of doing work. For diesel engine power is rated in units of HP.

IHP - indicated Horsepower.

Mechanical efficiency
- the ratio of engine BHP and its indicated HP. IHP is the power transmitted to the piston by the gas in the cylinder and is mathematically calculated.

Stroke – refers to distance piston travel from TDC to BDC.

TDC - top dead center.

Torque – measure of engine ability to apply generated power**.**

3. CONCLUSIONS

A glossary as alphabetically arranged reference work gives brief definitions of words related to a specific topic. It is also called *controlled* vocabulary. Glossaries are used to

-define all terms unfamiliar to an intelligent layperson.

-define all terms that have a special meaning.

-define all terms by giving their class and distinguishing features, unless some terms need expanded definitions.

In educational purposes, glossaries are a valuable instrument to present a set of terms and their definitions covering a certain theme or field. Playing the role of a reference or explanatory notes, a glossary serves to eliminate misunderstanding or confusion.

The ways of arrangement and layout may be different depending on teaching goals.

Writing a glossary may become a useful tool of self-education and self-correction for the students who take a test or perform a control assignment.

The mission of a teacher or an instructor is to suggest a glossary thematically properly arranged and full in its coverage of material in order to be able to meet students' requirements.

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TECHNO-ECONOMIC STUDY OF ELECTRIC CATAMARAN FERRYING PASSENGERS CROSSING KUALA TERENGGANU RIVER

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Catamaran floats on two demihulls, that are slimmer, shallower than single hull of an equivalent capacity, has less weight, small draught, more deck area for passengers and more stable. Due to these features catamaran may be powered by electric energy makes it more economical. Electric motors as the prime mover maintains high efficiency over a wide range of loads and speeds, has small weight, very low maintenance and repair cost compared to diesel engines or outboard motors. Battery is used as energy storage that enables the catamaran operates as ferry for transportation at rivers which is more efficiently due to its low operational cost; pollution free hence environmental friendly. The obstacle of this transportation system is that the distance to be traveled is limited and depends on the capacity of the battery. Recharging the battery should be done through an electric charger with high charging capacity per hour connected to the electricity line exist at the jetty. The monthly operational cost of catamaran boat is more less compare to the monohull diesel boat. Such type of ferry is effective for connecting two closed places on rivers or as a means of inland waterways transportation for tourism along rivers, canals or small lakes with limited sailing time. In this case the route is taken for Kuala Terengganu River at Kuala Terengganu, Malaysia.

Keywords: Catamaran, demihull, electric motor, pollution free, inland waterways.

1. INTRODUCTION

Kuala Terengganu city is the capital of Terengganu State in Malaysia. It is located at the eastern coast of Malaysia facing to the South China Sea. The river Kuala Terengganu splits the city into two parts the northern and southern parts. In the past people crossing the river by canoes, raft or sailing canoes, but since there are bridges most people traveling to the center of the city by car, however nowadays people still using boats/ferries to cross the river. At Figure 1 can be seen the monohull boats that are still used to carry passengers (10-15 passengers) crossing the river. The distance between jetty at "Seberang Takir" (Figure 2) and jetty close to the central market "Pasar Payang" shown at Figure 3 with signs is about 500 m.

Almost all boats that are now traveling along the river are monohull boats powered by outboard or inboard engines using fossil fuels where the exhaust gasses causing measurable negative effects on the earth's atmosphere so called the carbon emission. Beside that the boosting of oil price increases the operational cost of the boats/ferries especially when there is small number of passengers using the ferries hence it will not making profit but loss. Electric boat is not producing any pollution during its operation; no carbon emission, no engine waste cooling water and no noise [2]. The engine cooling water and the bilge wastewater which are pumped out into the river from the diesel boats that nowadays traveling at the river contains an amount of oil and fuel which will pollute the river and the sea. Besides that the exhaust gasses will pollute the air although at low rate, but after years when the number of boats increases due to the increase of the population and the number of local/international tourists hence the need of fossil fuels will increase and that will enhance the rate of air pollution.[1]. Yearly accumulations of the polluted elements boost the level of the river, sea and air pollution.

So it is wisely if there will be an effort to begin to reduce the pollution by transferring fossil fuel step by step to the green energies.

Fig. 1. Monohull boats at Jetty

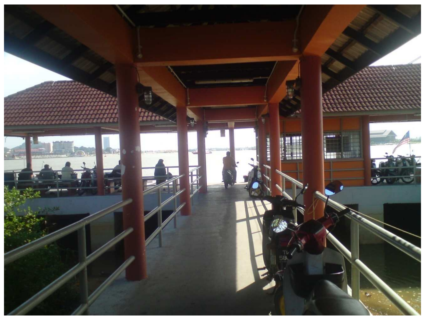

Fig. 2. Jetty at seberang Takir

Fig. 3. Map of Kuala Terengganu

2. BOAT DATA, RESISTANCE AND POWER SYSTEM

2.1. Monohull Boat

The design of a ship typically begins with analysis of the existing ships according to all of the requirements which are important to obtain general information on the type of particular boat that is the passenger boat. If the fulfilled of requirements with the successful design exists, the design might proceed using this boat as the basis boat and, thus, involve scaling its characteristics for changes intended in the design. It is necessary bringing the design, calculations and analysis of monohull which then fulfilled the requirement as a passenger's boat. Also evaluate the performance including the hydrostatic, speed, resistance, and power estimation by maxsurf software.

Small passengers boat that nowadays connect Seberang Takir and central market "Pasar Payang" are monohull boats that ferrying 10-15 seated passengers running 10 trips daily with service speed 10 knots. These boats were made by famous local boat builders at Kuala Terengganu without using drawings, made from hard wood and the boat shape is not changed much over the years.

Using maxsurf software with input data taken manually from the boat during the boat was on maintenance at the river bank is determined the body plan view of the boat at Figure 4 and the main dimensions at Table 1.

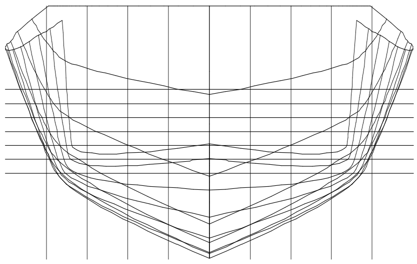

Fig. 4. Body plan view

Based on the boat dimension is determined the passenger space with dimensions, length 6m and width 1.8m has total area 10.8m^2 minus 1.5m^2 (area of the engine casing), so the space for one passenger is only about 0.65m^2.

Table 1: Main dimension of monohull boat

Displacement	2.007	tonne
Volume	1.958	m^3
Draft to Baseline	0.388	m
Immersed depth	0.388	m
Lwl	7.603	m
Beam wl	1.874	m
WSA	13.149	m^2
Waterplane area	12.301	m^2
Cp	0.622	
Cb	0.354	
Cm	0.57	
Cwp	0.863	
KB	0.277	m
GMt	1.447	m

Table 2: Monohull boat speed versus resistance and power

Speed, kts	Resistance, kN	Power, kW
0	0	0
1	0.01	0.01
2	0.04	0.04
3	0.08	0.12
4	0.15	0.3
5	0.29	0.74
6	0.48	1.48
7	0.9	3.25
8	1.29	5.3
9	1.69	7.8
10	1.99	10.22

2.1.1. Water Resistance and Engine Power

Water resistance of a ship could be determined by various method of resistance calculation, Formula of total water resistance of a ship is: $R_T = ½ C_T*ρ*V^2*S$,

Where : R_T – Total Resistance (kN)
C_T – Total resistance coefficient
P – Seawater density (t/m^3)
V – Ship speed (m/sec)
S – Wetted surface area (m^2)

Table 2 shows the result of resistance and power prediction with Holtrop method at the maxsurf software, where at speed 10 knots the resistance is 1.99kN and the power is 10.22kW ≈ 11kW, that is in accordance with the power of the engine using at the boat analyzed in this study.

2.1.2 Diesel Power System

Diesel power system where diesel engine is the main engine where its rpm is reduced by the gearbox when reach the propeller shaft. The speed controller is located in front of the engine which is regulated by the boat driver (see Figure 5). Commonly brake specific fuel consumption (BSFC) of diesel engine is expressed in units of grams per kilowatt-hour (g/(kW·h)). The engine power is 11 kW, BSFC = 0.25 g/(kW.h), daily engine operating hours is 1.67 hours, daily fuel consumption is 5.8 litres [8].

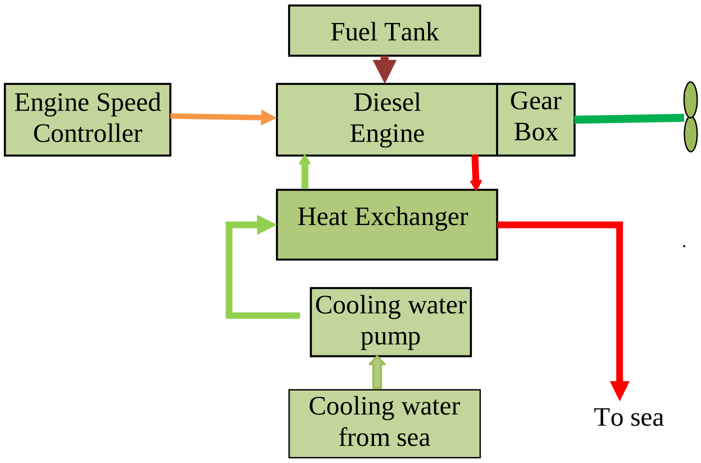

Fig. 5. Diesel boat engine/propulsion system

2.2 Catamaran Boat

Small catamaran shown at Figure 6 that can carry 20 passengers and at Figure 7 is shown it's body plan. According to the main dimension of the catamaran stated at Table 3, the deck space for one passenger is determined about 1.6m^2.

Fig. 6. Small passenger catamaran

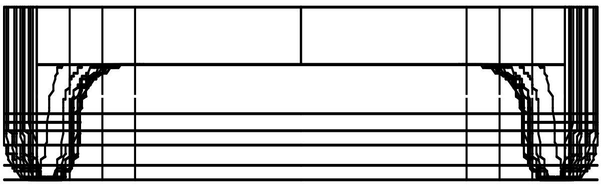

Fig. 7. Body plan view of catamaran

Table 3: Main dimension of catamaran boat

Displacement	**2.088**	**tonnes**
Volume	**2.037**	**m^3**
Draft to Baseline	**0.383**	**m**
Immersed depth	**0.383**	**m**
Lwl	**9.174**	**m**
Beam wl	**3.85**	**m**
WSA	**17.085**	**m^2**
Max cross sect	**0.292**	**m^2**
Waterplane area	**6.42**	**m^2**
Cp	**0.762**	
Cb	**0.638**	
Cm	**0.838**	
Cwp	**0.77**	

2.2.1 Catamaran Resistance and Power

Table 4 shows the result of water resistance and power prediction of the catamaran predicted with Holtrop method at maxsurf software.

Table 4: Speed versus resistance and power

Speed, kts	Resistance, kN	Power, kW
0	0	0
1	0.04	0.02
2	0.11	0.12
3	0.21	0.33
4	0.38	0.83
5	0.54	1.41
6	0.71	2.20
7	0.97	3.58
8	1.17	4.90
9	1.39	6.43
10	1.67	8.78

2.2.2 Electric Power System

AC/DC electrical charger placed on the jetty using public electricity line as electrical source then stored the electricity in the batteries placed on board as the electric source to run the brushless electric motor as prime mover of the boat. This system is more economical compare with the diesel engine at same capacity which is used at mono-hull boat compare Table 4 and Table 2.

The equipments used at the electric catamaran boat are:

- Electric charger (at jetty) capacity : 220V AC , 60A DC 48 V
- Battery capacity : 500 AH, 48 V
- Capacity of the electric Motors : 9 kW, 48 V DC

The patterns of the electric motor-propeller system of the electric boat at Fig. 8 shows that the electric charger will charge the batteries then the dc current from the batteries through the speed controllers will control the speed of the electric motor which runs the propeller. Electric motor as prime mover has following advantages: easy and low cost of maintenance and repair, no use of fuel hence reduce the operational cost and the carbon dioxide emission.

Electric motor has long life time service and has high efficiency about 93 %. Besides that this system does not need thrust bearing because the electric motor delivers the propeller thrust directly to the boat hull [6].

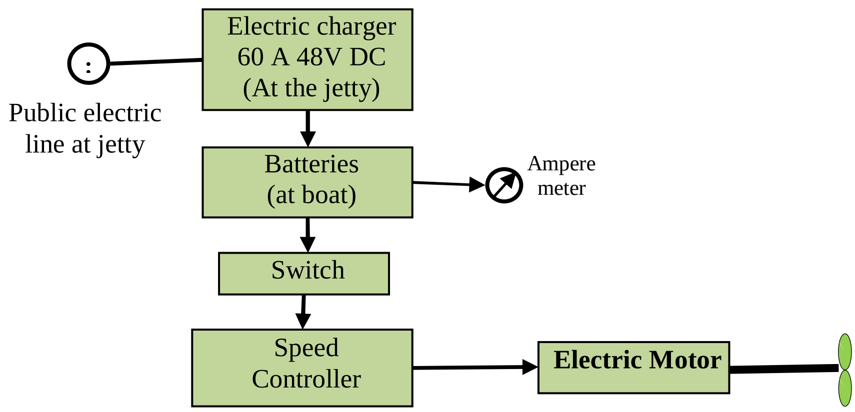

Fig. 8. Electric Boat propulsion system

Electric motors maintain high efficiency over a wide range of loads and speed, they run up to 48 volts which generate power until 10 KW ≈ 13 HP with low shaft speed and high torque they are enable to use a simple, cheap and efficient transmission system in most application. These motors enable us to get the best possible performance from the batteries. High efficiency gives longer running time and less frequent battery replacement [7].

3. RESULT AND DISCUSSION

3.1 Resistance, Power and Passenger Space

This study is focused on implementing the electric catamaran on place of the traditional monohull boats powering by engines using fossil fuels.crossing the Kuala Terengganu River From the result of resistance and power calculation using maxsurf software is determined that at speed 10 knots the resistance of catamaran is 1.67kN, and monohull boat 1.99kN, which stated that catamaran has 20% less resistance, hence 20% less engine power compare to monohull.

Besides that the deck area for one passenger at monohull is 0.65 m^2 and 1.6 m^2 at catamaran. The sitting position of the passengers at monohull is facing each other, but at catamaran the passengers are sitting heading to the front of the boat and have a good view to the surroundings, so it is more conveniently at catamaran.

3.2 Income

The income of the boat depends on the daily average passenger's number which is assumed 8 passengers for one-way trip during the whole 10 trips daily. Based on the collected data the boats operate 12 hours a day. The total operating days per year is 300 days with ticket price MYR1 for one way travelling so the projected monthly income for both boat types will be the same (see Table 5).

3.3 Operational Cost

The monthly operational cost of a boat with outboard, inboard engine or electric motor depends on the following items:

- Number of daily trips and operational hours
- Main engine power
- Operational cost, crew salary
- Maintenance and repair cost [4] and [5]

3.4 Profit

Based on the income, operational cost and crew salary is determined the monthly profit of each type of boat which is shown at Table 5.

Table 5: Monthly income, operational cost, salary and profit, MYR

Number of Trip	Monthly income	Monthly oper.Cost		Monthly Salary	Monthly Profit	
		Diesel monohull	Electr. cat		Diesel monohull	Electr cat
4	1920	335	19	400	1185	1501
5	2400	373	29	500	1527	1871
6	2880	418	39	600	1862	2241
7	3360	468	49	700	2192	2611
8	3840	524	59	800	2516	2981
9	4320	587	68	900	2833	3352
10	4800	655	78	1000	3145	3722
11	5280	729	88	1100	3451	4092
12	5760	810	98	1200	3750	4462

3.5 Carbon Emission, Sound and Waste Water

The carbon emission exhaust into the air by engines using fossil fuels is using one liter petrol sends 2.3kg CO_2 into the air and using 1 liter diesel fuel exhaust 2.7kg CO_2[6]. Specific fuel consumption of small diesel engine is 0.25 g/kW.h. Daily fuel consumption is about 5.8litres, yearly 300x5.8.=1740litres Yearly exhausted CO2 will be 1740 x 2.7 x 0.4 = 696 kg CO_2. There are more than 30 boats sailing along the Kuala Terengganu river daily so approximately 20880kg of CO_2 will be exhausted into the air.daily

Directly thrown the engine cooling water and bilge wastewater into the river will pollute it, but electrical catamaran has no carbon emission, no bilge wastewater contained with oil and no sound pollution disturbance by the engine [3], hence during travelling the passengers on electric boats can talk to each other clearly and breathing fresh air without the smell of fuel and exhaust gas.

4. CONCLUSIONS

Based on the predicted resistance, power, main dimension and monthly profit of both boats reveals that electric catamaran is pollution free and more efficient than diesel monohull boat, where:

- Electric catamaran boat has less resistance and power.
- Passengers are more convenient due to more space, good sight to the surroundings; talk to each other without engine noise interference.
- More profit.
- No carbon emission, no waste water.

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NOMENCLATURE

C_b	Block coefficient
C_m	Midship coefficient
C_p	Prismatic coefficient
C_{wp}	Waterplane coefficient
GM_t	Transverse metacenter height (m)
KB	Height of center of buoyancy (m)
L_{WL}	Length of waterline (m)
WSA	Wetted surface area (m^2)

MARINE PRACTICE GUIDELINES FOR FUEL CELL APPLICATIONS

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This paper focuses on the implementation of fuel cells in marine systems as a propulsion system and energy source. The objective is to provide an overview of the pertinent legislation for marine applications of fuel cells. This work includes a characterization of some guidelines for the safe application of fuel cell systems on ships. It also describes two ships that have implemented fuel cells to obtain energy, the Viking Lady, the first marine ship to include this technology, and Greentug, a reference for new tugs.

Keywords*:* fuel cell, guidelines, marine applications, prototypes, system implementation

1. INTRODUCTION

In recent years, there has been increased public concern about the potential environmental impact of shipping [1]. Always maritime industry has responded to the restrictions imposed to protect the environment through optimization and development of different systems of internal combustion engines. Recently, the environmental concern is made evident by the use of new technologies and/or fuels for marine applications. Some examples of the interest to produce energy with lower environmental cost would be the cases presented below:

- The Company Balèaria, which operates between the Balearic Islands and the Iberian Peninsula, intends to re-engine four of its high speed vessels for using LNG instead of diesel. It aims to reduce maintenance and operating costs as well as to comply with future environmental standards. Using natural gas reduces 25% of CO_2 emissions and eliminates other emissions types [2].
- The ports of Rotterdam and Gothenburg, two of the largest in Europe, will sign an agreement to promote use of LNG as fuel for shipping. Both ports belong to the "Sulphur Emission Control Area" (SECA) in northern Europe, where from 2015 will begin to take effect very strict regulations regarding the sulfur content in fuels. In the case of the port of Gothenburg the construction of a new terminal that will include the supply of LNG has begun to be studied. The aim is to have infrastructure for LNG bunkering available once the sulphur regulations come into effect. Sulphur and particle emissions would be reduced to almost zero, nitrogen oxide emissions by 85-90 per cent and net greenhouse gases by 15-20 per cent [3].

In many cases, the primary aim is to minimize the environmental footprint of ships operating in densely populated coastal regions and biologically sensitive marine areas. With this idea in mind, an alternative solution to traditional propulsion systems to produce electricity without emissions of SOx, NOx and CO_2 proposes using fuel cells [4]. The needs that require the installation of fuel cells involve investing large amounts of money in addition to the need for more experience in what relates to the field of application and the safety. Also the hydrogen low density states important storage problem, which add additional safety problems.

2. MARINE GUIDELINES

The guidelines for the safe application of fuel cell systems on ships are summarized and compared in Table 1.

Table 1: Comparison of guidelines [5, 6, 7]

	Bureau Veritas	Germanischer Lloyds	Det Norske Veritas
General requirements			
Guidelines applying to the use of fuel cell systems installed on ships. (Applicability to new ships to be determined by the classification society.)	✓	✓	✓
Documentation to be submitted			
-Description of the equipment.	✓	✓	✓
-Electric circuit diagrams.	✓	✓	✓
-Automation concept.	✓	✓	✓
-Fire extinguishing concept.	✓	✓	✓
-Plans of hazardous areas and safety and emergency concept.	✓	✓	✓
-Physical environment and operating conditions.	✓		✓
Testing and trials	✓	✓	
Ship arrangement and system design			
Materials used in gas installations must be in accordance with the Rules for the Classification of Ships.	✓	✓	✓
Austenitic stainless steel shall be used for materials in contact with hydrogen. Other materials may be approved after special consideration.	✓	✓	✓
The geometry of the arrangement and location of spaces must be simple.	✓	✓	✓
The ventilation system used for hazardous spaces must be separate from the system used for non-hazardous spaces.	✓	✓	✓
Fire safety			
Detection system in tank room and FC spaces.	✓	✓	✓
Definition of hazardous zones.	✓	✓	✓
Fire extinction.	✓	✓	✓
Control, regulating, monitoring and alarm devices			

Gas tank monitoring.	✓	✓	✓
Gas compressor monitoring.	✓		✓
Fuel cell power system monitoring.	✓	✓	✓
Monitoring of chemical reactions.		✓	
Electrical systems			
Area classification.	✓		✓
In general, electrical equipment and wiring must not be installed in hazardous areas unless essential for operational purposes.	✓		✓
Power supply connections must not allow the ingress of gaseous mixtures where gas fuel leaks are possible.	✓		✓
Manufacture, workmanship and testing.			
Liquefied gas tank.	✓	✓	✓
FC fuel piping systems.	✓	✓	✓
Onboard testing of FC plant.	✓	✓	✓

One set of guidelines, from ***Bureau Veritas***, is described in greater detail below. These are the marine guidelines applied to **'Greentug'**, the reference for new tugs.

-Materials

Components containing natural gas or hydrogen must comply with the provisions of the IGC Code (the International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk). For non-cryogenic gas, particularly compressed gas, other non-metallic materials may be applied subject to special examination.

Components in contact with hydrogen must be made of materials having good compatibility with respect to embrittlement and hydrogen attack phenomena. The normal operating temperature range for materials used in hydrogen components should be -40℃ to +85℃ (normal conditions including filling and disc harging). References to hydrogen-compatible materials and suitability demonstration testing are included in the guidelines. Non-metallic piping carrying hydrogen gas may accumulate electrostatic charge along its exterior surface. Discharges from the external surface of the pipe may be sufficient to ignite a flammable mixture of gas or vapor in the surrounding environment. Care must be taken to effectively mitigate this risk.

-General arrangement

Machinery spaces characterized by its geometry and distribution system design safety control should be such that in case of leakage without loss of vessel's essential functions (propulsion, government and maneuver).

The main distribution of spacious for fuel, distribution, storage, processing and use must comply with the conditions so that the extent of the danger zones is kept to a minimum. Besides presenting a simple geometry to avoid trapping explosive mixtures. Gas fuel storage, gas compressors, fuel processing systems, fuel cell modules and power conditioning systems must be located in different areas. Spaces containing fuel processing equipment must comply with the same requirements as machinery spaces housing fuel cell stacks.

-Gas fuel supply

All gas supply piping within gas-safe machinery space boundaries must be contained by a gas-tight enclosure, i.e., double-wall piping or ducting. Low-pressure gas supply piping (under 10 bar) located within ESD-protected machinery spaces equipped with an individual exhaust ventilation system may be accepted without a gas-tight external enclosure if the areas occupied by flanges, valves and other components of the gas supply system are gas-tight enclosed. (Arrangements in machinery spaces are such that the spaces are considered non-hazardous under normal conditions, but under certain abnormal conditions may have the potential to become hazardous.)

Ventilation systems for gas supply line ducts must always be in operation when there is gas in the pipe system. Continuous gas detection is recommended for each gas supply line to indicate leaks and to trigger shutdown of the gas supply to the machinery space. The master gas fuel valve must close automatically if the air flow is not established and maintained by the exhaust ventilation system.

Arrangements for provision of the necessary flexibility must be demonstrated to maintain the integrity of the piping system in all foreseen service situations. The guidelines pay special attention to the application of different types of valves and their location in the gas piping system.

-Gas fuel storage

The fuel gas can stored in liquid or high pressure, in these cases the gas storage tank must be of type C, thus fulfilling the conditions of the IGC Code. It must be possible to empty and purge gas and vent bunker tanks with gas piping systems. Inerting must be performed prior to venting to avoid an explosion in hazardous atmospheres in storage tanks and gas pipes. If hydrogen is used, fuel inerting is preferably achieved using helium, which cannot freeze and form a plug when exposed to cold hydrogen. Air must be prevented from entering the piping system and storage tanks in order to prevent the formation of flammable mixtures. The system must be designed to withstand at least twice the anticipated number of filling cycles.

The design and construction of compressed gas storage tanks must be in accordance with recognized standards (e.g. BV Rules, Pt C, Ch 1, Sec 3). Applicability of the standards chosen for the containment system to seagoing conditions must be demonstrated. Pressure relief valves must be fitted. The system must be designed to withstand the anticipated filling cycles for the lifetime of the ship.

The guidelines provide specific recommendations for the onboard location of gas fuel storage tanks and batteries to protect them in the event of a collision or grounding, with 760 mm as the absolute minimum inboard distance from the side shell. For liquid hydrogen storage, the inner pressure vessel must be designed to operate at a temperature of -253℃. In this state, liquid gas can be stored at a maximum acceptable working pressure of 10 bar. Storage of compressed gas below deck may be permitted after special consideration if requirements are met regarding relief valve settings, thermal protection, gas detection, ventilation and fixed fire extinguishing. The storage tank and associated valves and piping must be located in a space designed to act as a second barrier for liquid or compressed gas leakage. On ships where essential services depend on the fuel cell system, fuel storage must be divided between two or more tanks of approximately equal size, located in separate compartments.

-Electrical equipment

In general, electrical equipment and wiring may not be installed in hazardous areas (areas where an explosive gas atmosphere or a flammable gas (flash point below 60℃) is or may be expected to be present) unless necessary for operational purposes. The type of equipment and installation requirements must comply with the relevant area classification, considering three types of dangerous zones (0, 1 and 2; see IEC 60079-10 and IEC 60092-502).

-Ventilation systems

Ventilation is a key safety feature of gas-fueled power systems. Good air circulation in all spaces is of paramount importance, particularly for preventing the formation of explosive gas mixture pockets in the space. The guidelines provide extensive recommendations for the forced ventilation of gas-related spaces and gas pipe ducting, and for the location of ventilation inlets and outlets and pressure relief outlets. The ventilation system for machinery spaces containing gas utilization equipment must be independent of all other ventilation systems. Ventilation must be monitored, including alarms. Electrical installations must be disconnected if ventilation cannot be restored for an extended period. Any ducting used for the ventilation of hazardous spaces must be separated from that used for the ventilation of non-hazardous spaces. Means must be provided to indicate any loss of the required ventilation capacity.

-Detection, monitoring and control

In order to provide the operator (or operating system) with the required information to safely operate the fuel cell power system, several detection and monitoring systems must be installed. Typical examples are gas detectors (at different levels of the Lower Flammable Limit (LFL) of the gas considered), loss of ventilation detectors, fire detectors, and gas pressure monitoring systems. The guidelines provide a detailed table (monitoring the fuel cell installation), highlighting the use of the different monitoring and detection systems, associated alarms, and follow-up actions (automatic shutdown of the main tank valve or automatic shutdown of the gas supply to the affected machinery space). For gas detection at 40% LFL, two independent gas detectors located close together are required for redundancy reasons, unless the gas detector is the self-monitoring type. Redundancy for the detection of critical hydrogen concentration is also considered in order to account for possible detector failure.

-Risk analysis

A risk analysis of the fuel cell installation systems must be performed to assess the consequences of a failure affecting the relevant systems and/or a gas leak. The required analysis can be an FTA (Fault Tree Analysis), FMEA (Failure Modes and Effects Analysis), HAZOP (Hazard and Operability Study), a combination of these techniques, or another type of analysis providing equivalent information. The risk analysis must be based on the single failure concept, which means that only one failure must be considered at the same time. Both detectable and non-electable failures must be considered. Consequence failures, i.e., failures of any component caused directly by a single failure of another component, must also be considered.

-Tests and trials

Factory testing is required for materials, components and system assemblies. The complete installation must be tested on board. Lists and descriptions of tests that must be performed, or were already performed (for type-approved equipment), must be defined and submitted for approval. Specific tests are needed for components in contact with hydrogen. (The relevant tests could be derived from approval tests for car hydrogen tanks.)

The guidelines provide test recommendations for gas tanks and gas piping in accordance with the IGC Code and the interim BLG (Bulk Liquids and Gases) guidelines, including welding tests, post-assembly hydrostatic tests, and onboard system tests.

-Operational recommendations

The guidelines provide specific operational and training requirements with regard to system operation and maintenance. Recommendations are provided for the operating manual and maintenance manuals and for the special training of crew members with direct responsibility for gas-related operations [5].

3. PROTOTYPES AND APPLICATIONS

Capabilities for improving fuel cell technology are currently growing, along with the use of fuel cells in practical cases (i.e., ship propulsion systems and electrical systems). These are the reasons for developing practical guidelines for marine applications. We know of different cases where this technology has been employed, and have described the applicable guidelines in previous sections. To illustrate the above, we have included a description of the ships we consider most relevant to our paper.

- ***Viking Lady***

The Viking Lady, Fig. 1 and Table 2, a supply ship, was the first ocean-going ship to use fuel cells. It is equipped with hydrogen fuel cells, extracted from LNG, and batteries providing sufficient electrical power for its electrical systems. It uses a diesel engine for main propulsion, Fig. 2.

The FellowSHIP Project started in 2003, and focused on finding new solutions to reduce CO_2 emissions by 50% and NO_x and SO_x emissions by 100% in marine applications. It also sought to reduce fuel consumption by 30-35%. The project had three phases:

- One (2003): Initial studies and designs.
- Two (2007-2010): Once the fuel cells were studied, they were integrated into the electrical system and the new control system developed for this prototype ship. Construction of the Viking Lady took place during this phase.
- Three (2010-2013): After the ship was built and launched, a research program began using informatics tools and different kinds of estimators to predict fuel cell behavior under marine conditions, based on the ship's performance.

Fig. 1. Viking Lady (http://vikinglady.no/technology/)

Several tests found that the ship was only able to operate with fuel cells and batteries at low speed and low power, which are therefore advisable for use in port. This capacity is of great interest because the ship is designed to sail in the North Sea, where there are strict regulations on gas emissions. We can also see that fuel cells provide valuable support to the main engine when the ship is supplying fuel. Another important advantage was the reduction of vibrations, of particular interest when the ship is using the dynamic positioning system.

Table 2: Viking Lady specifications

Delivery (year)	2009
Length	92.2 m
Width	21 m
Depth	7.6 m
Gross tonnage	6100 tm
Dead weight	5900 tm
Berths	25 persons
IMO no.	9409675
Class	DNV 1A1 Supply Vessel
Ship owner	Eidesvik Offshore

The system for generating electrical power, Fig. 2, consists of fuel cells and a series of batteries by Corvus Energy (Canada). These are comprised of 6.5 kW lithium-polymer modules. This group of batteries is monitored by a control system that indicates when they are charged or empty, on or off. There is also, Fig. 3, a monitor to indicate the starting and stopping parameters.

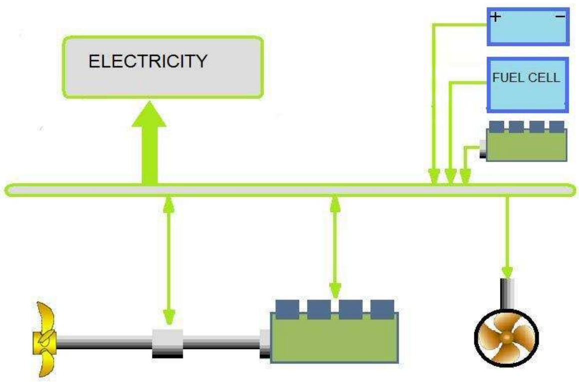

Fig. 2. The electricity network and distribution (electricity is produced by batteries and fuel cells), along with the independent propulsion system

The fuel cell pack on the Viking Lady has roughly 18.5 hours of autonomy while operating at up to 500 kW of power. In the beginning, the minimum power established was 320 kW.

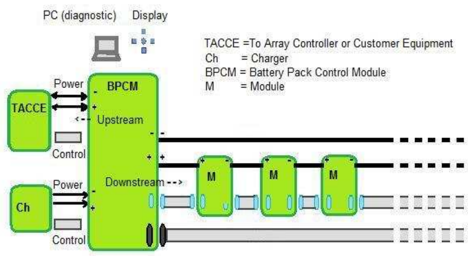

Fig. 3. Battery system

These are Molten-Carbonate Fuel Cells (MCFC). They operate at high temperatures, making it necessary to reach 550-650ºC. This could be an advantage: no external transformation of LNG into hydrogen is necessary because it is directly dissociated. Because it is a basic electrolyte cell (Li_2CO_3/Na_2CO_3), the carbon ions travel rather than the protons. Their yield is about 54%, and they can supply 200 to 2000 kW of power, supporting temperatures up to 600-800ºC. CO_2 is generated during the electrical reactions. However, the CO_2 produced is the same that was taken from the atmosphere.

This type of cell has several advantages. They are very efficient because they take advantage of the high temperatures in gas and steam turbines to increase efficiency. There is no CO_2 poisoning in the anodes because no CO_2 is generated. Finally, they allow for the use of a wide range of fuels. However, there are also some disadvantages. These include the need to increase the temperatures (which can also be an advantage, as explained above), high costs, and the instability and fragility of the electrolyte [8, 9].

The Viking Lady project involved an investment of 5 million Euros, of which only 60% was contributed by shareholders and 40% was provided by the Norwegian government. The Viking Lady had some supporters without which it could not have been completed:

- DNV (Det Norske Veritas): A classification society that safeguards the safety of persons and the environment, which promotes the certification and classification of services for the global market (Table 3).
- Eidesvik Offshore, a specialized shipping company with a fleet of supply ships that fully supported the project.
- Wärtsilä, a leading marine propulsion company that designed the ship's electrical power plant.

The project also received support from the Norwegian Ministerial Council and the German Departments of Innovation, Economy, Environment and Technology.

It was determined that a decrease in CO_2 emissions equivalent to 22,000 cars per year can be achieved through this project. NO_x emissions are decreased by 180 tons. A decrease in fuel consumption has also been observed. The project offers greater operational safety, requires less maintenance, and can result in decreased vibrations. The problem with this technology is the high cost, due to its limited development, although it is estimated that the ship will become profitable two years after construction [10].

- ***Greentug***

Greentug, Table 3 and Fig. 4, still in draft form, is a reference for new tugs. Greentug is a hybrid ship with an electrical system powered by a fuel cell and main propulsion provided by diesel engines. It is capable of reducing SO_x and NO_x production by 90% and CO_2 by 50%. Like the Viking Lady, it is designed to operate in the North Sea, in the ports of Rotterdam and Amsterdam.

Table 3. Greentug specifications

Length	30.95 m
Width	12.00 m
Depth	5.3 m
Velocity	13 kn
Dead weight	65 tm

The power generator set consists of a fuel cell system, and the fuel cell system is comprised of a series of lithium-ion batteries with a range of about eight and a half hours.

The battery packs are used to handle power peaks, while the remaining electrical demand will be covered by the fuel cell system.

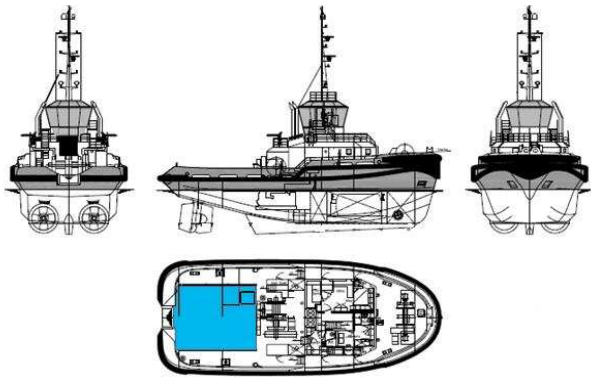

Fig. 4. Plans for Greentug [12]

The fuel cell system is comprised of two generator sets capable of generating 100 kW of power each. The PEM cell was supplied by NedStack Fuel Cell Technology, and provides an efficiency of 34%. These fuel cells use a solid polymer electrolyte and a platinum catalyst. They have an operating temperature range of 60-120°C. In this type of stack, the elements transferred from the anode to the cathode are protons (H^+) [8, 9].

The fuel used is hydrogen, stored in 1000 kg (833 m^3) tanks at a storage pressure of 430Ba. This type of fuel cell provides a fast start feature, operates at low temperatures and is low-corrosion, but requires hydration and is very sensitive to CO [11].

Propulsion power is supplied by a series of diesel combustion engines, two of which are capable of providing 950 kW of power and two providing 1200 kW. It is equipped with a 113 m^3 fuel oil tank. Because it is a tugboat, an optimization study was conducted to determine the weight distribution of the fuel cells.

Electrical power will be used for relief efforts. When the vessel sails in green mode, it will achieve zero emissions during operations and will stop browsing for about one hour at a speed of 7 knots.

The project is supported by: Smit Engineering, Bakker Sliedrecht, Electro Industrie, MARIN, Bureau Veritas, Nedstack Fuel Cell Technology, TNO Science and Industry, and LindeGas Benelux.

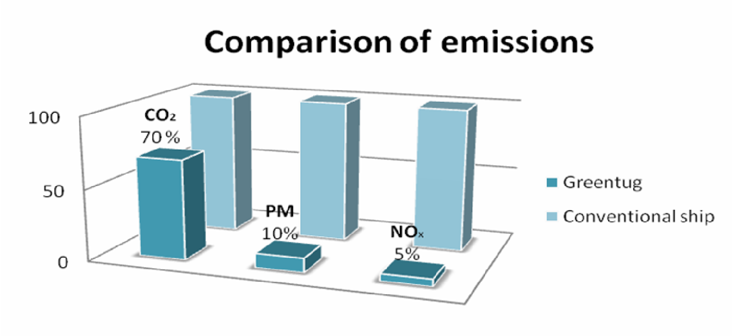

Fig. 5. Graph comparing emissions from Greentug and conventional ships (adapted from [13])

Greentug will be capable of reducing emissions to 0 during temporary green operations, and will operate using only fuel cells 85% of the time. Emissions will be considerably reduced in other operating modes, Fig. 5, and significant fuel savings will be achieved. However, as with any new technology, costs will be high [11, 12, 13].

4. CONCLUSIONS

Fuel cell power supplies show high potential for growth, and efforts by classification societies to develop guidelines are an indicator of future expectations for fuel cells. The development of guidelines is dependent on future demand for such power supplies and improvements to certain technical aspects, as well as the contribution of current regulations to ship safety. However, time is needed to respond to these challenges. Another problem that conditions this technology is the source of the fuel (hydrogen), which must be economically viable and provided by renewable energy sources.

This paper introduces two innovative projects, Viking Lady and Greentug that shed light on the viability of such systems from a safety and economic perspective. This provides information on the possibilities of these systems as an alternative to traditional petroleum-based propulsion systems.

ACKNOWLEDGEMENTS

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SAFE ACCESS AND OPERATIONS WITHIN PORT AREA

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An important aspect of all operations performed in port area is safety. This means protection of marine environment, port structure, facilities and human's life. The paper offers an overview of some important points, concerning safe berthing access, navigation and safety performing of cargo handling operations within the port area.

Keywords: port, safe access, navigation, operational safety

1. ENVIRONMENTAL FACTORS INFLUENCED ON SAFE ACCESS AND NAVIGATION

Environmental factors take effect to shipping, port building and port operations. The certain factors are based on geomorphic, morphodynamic, sedimentary and hydrodynamic characteristics of port area. In Figure 1 are shown the environmental factors ensuring safe access and navigation within the port by shipping. The weather factors include generally wind and its characteristic (velocity, gust), visibility (fog, mist or heavy rain), barometric pressure (low or high). The main influences of current are tides, winds, atmospheric pressure, oceanic current incursions, density stratification with depth, seabed bathymetry and coastline shape or constructions. The reduction in available navigable water may be caused by building up the depth alongside the birth with silt. Changes in swell and wave characteristics may be engendered by shallowing effects, barometric changes, changes in beach morphology. Presence of jelly-fish, algal blooms can pose a threat to ship's seawater engine coolant intakes. Similar effect occurs from suspended sediments and silts in narrow channels. Under changes to water density is implied transition from open sea to fresh water, fresh water wedges in river ports and influence of suspended sediment from major dredging operations. Slopes of rivers affect water depth, water density and water flow (Maritime Safety Authority, 2005).

Safety navigation and operation availability in each port should not be less than 90-95%yearly. The availability of berth can be subdivided into navigation and operational availability. Navigation availability describes the time, in which port is safety and the berthing on quay is available. Operational availability describes the time, in which the loading and discharging processes can be performed. The total safety can be calculated as a sum of safety from design on constructions, safety on personnel and operational safety. The berthing of a larger ship is always a hazardous operation, which may damage resulting in consequential losses in the operation of the facility or the terminal. Table 1 shows the relative highest possibility of a accident occurring during each phase of the total navigational operation, ranging from arriving to departure, for example of an oil tanker due to oil spillage (Thoresen C. A., 2010).

The environmental protection from oil pollution and spillage of residues take an important place on safety within port area. Response to marine pollution incidents requires careful advance planning to ensure that the impact of the pollution is minimized. The presence of oil spill equipment and facilities at a nearby spill response centre will make it possible to reach the oil spill site as fast as possible. Using of inappropriate shore facilities for collection of residues can also cause pollution. Therefore taking the residues from ships and their disposal in an environmentally safe manner has to be performed in accordance with international, national, regional and local laws and regulations. The delivery of residues to shore involves the ship and operating activities as well as safely aspects, the competent port authority should supervise such actions and bring them into line the other port safety requirements (Dimitrova V., 2007).

For successfully operating of ships into and out of ports it is essential to apply an accurate assessment of the relevant environmental phenomena, which will have influence and will pose potential risk for safety on the area. Generally, a safety zone is an area of water and/or land designated for a certain time for safety or environmental purposes. To protect human safety or the environment, a safety zone will limit public access to the area.

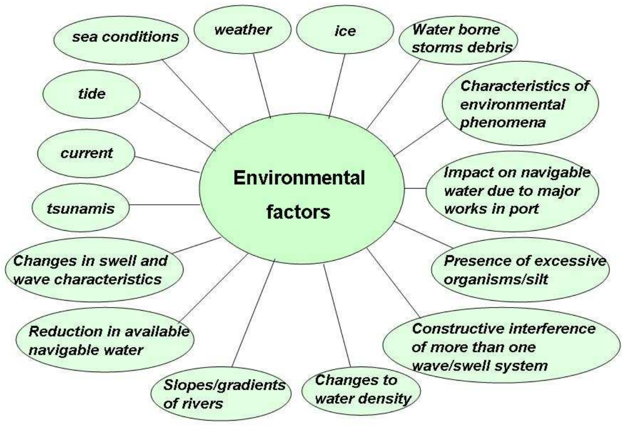

Fig. 1. Environmental factors for assessment of safety access and navigation

The purpose of safety regulations writing should be to prescribe procedures for establishing different types of limited or controlled access areas and regulated navigation areas; general regulations for different types of limited or controlled access areas and regulated navigation areas; specific requirements for established areas and to list specific areas and their boundaries.

Regulated navigation areas and limited access should be water areas within a defined boundary for which regulations for vessels navigating within the area have been established. Vessel traffic has to be controlled and place with hazardous conditions to be clearly determined. It is preferable that each port to have a prescription what type or size of vessels may enter an area or in what manner they must navigate(USA Coast Guard, 2007).

It is considered that all ports should have certain minimum equipment requirements for the assessment of environmental conditions in order to operate at a minimum safety level. Moreover the environmental factors can be categorized in connection with term of assessment on one-day decision making (real time monitoring), short and medium term (forecasting and prediction) and long term (modeling and planning). Real time monitoring of these conditions is most effective way to determine the safe access in and out of port. Operational decisions affecting vessel's safety in the maritime environment can be taken basis on following states: 1) safe approach to the port; 2) safe enter and berthing/unberthing and departure; 3) requirement and necessarily for using of tug assistance; 4) safety on concurrent ship movements into a shipping channels or constructed water areas; and 5) safe performing of cargo handling operations. Provision of accurate and reliable real-time data provides directly to those making operational decisions can only assist in making correct and safe decisions. Operational decisions should be supported by good safety management system practices. They are vital for the safe operation of the port in full range of environmental conditions that can be expected at that location.

Table 1: Possibility of on accident during each phase of navigational operation

	Possibility for accident to		
	Berth structure	**Personnel**	**Environment**
Arriving outer-harbour basin	-	-	3
Turning in harbour basin	1	-	3
Berthing operation	3	2	3
Mooring	3	1	1
Loading/unloading	1	3	2
At berth due to a bad weather	3	1	2
Unberthing operation	2	-	3
Departure from port	-	-	3
Legend: 1- small possibility; 2-medium possibility; 3- high possibility.			

Port authorities have duty to send the actual information about condition relating to the weather situation and port facilities and to ensure provision of port related aids to navigation. For example, in case there is a wreck in water, which is a hazard to navigation, the port authority should mark the area rather than the wreck is removed.

In order to provide safe access routes for the movement of vessel traffic proceeding to or from ports the study and evaluation of port access route will be very helpful for further improving of vessel's traffic system. The evaluating of existing routing measures should include: the nature, volume and frequency of vessel's traffic; the risk of collisions, spills and damages associated with this traffic; the impact of installation, expansion or improvement or vessel's traffic system; all other relevant costs and data.

2. OPERATIONAL SAFETY

The innovations in port make a substantial change in their activity and take effect to the cargo handling technologies, such as introduction of modern labor-saving devices for internal traffic or of completely new types of stevedoring gear, which simplify or speed up the handling of heavy loads; introduction of special systems, which allows implementation of multi-modal carriage; and introduction of systems for rapid exchange of information in order to control the flow of data documentation and work procedures.

Safety of operations within the port can be considered in following directions: safety of vehicles and their drivers; safety of lifting equipment, cranes and other cargo hoisting and hauling devices; safety of human working over and near the water, at height; and safety of cargo area – reducing the spillage, dusty cargoes, slips and trips, and confined spaces.

Every workspace should be safe for the people and vehicles using it. Vehicles and pedestrians should be separated where they share the same workspace. Walking within port area should be permitted only is this is essential for performing of work operation. On the other hand vehicles should be provided with suitable visibility aids, regularly maintained, repaired and inspected. They must be equipped with rotating warning lights or with warning signals. All drivers should follow safe working practice and be competent and skilled to operate with the relevant vehicle. Motorized vehicles may not be driven or parked in flammable zones in oil port without obtaining of specific permission and electric engine heater must be of an approval.

Loading and unloading at ports involves using of various lifting equipment. This may be including gantry cranes, slewing cranes, forklift trucks, etc. For reducing of risk from accidents with lifting equipment should be taken into consideration following measures: using always on suitable lifting equipment to securely lift cargo; the lifting operation have to be under appropriate plan, which includes work, route, weight slinging/spreader method and instruction in case of shifted load or bad weather; it has to be forbidden lifting or passing over the pedestrians; in case ship's lifting equipment is used, it has to be ensured that they are suitable for the performing of the operation.

Non-adherence to the port procedures and instructions could lead not only to accidents and damages port property, but also can endanger the human healthy. Therefore working at height have to be avoided or limited and operations to be performed from the ground by long handled tool. Human have always wear high visibility clothing in port area when operations are ongoing. The personnel protective equipment such as lifejackets or buoyancy aids, in case of working over or near water, should be obligatory worm. Safety hats must be worn in the vicinity of hanging cargo or where there is a risk of falling objects.

Wet or icy surfaces on loads, badly stowed lifting equipment such as ropes, cables, containers lashing gear, discarded packaging and pallets or spilled rest of cargo can cause slips and trips. In this respect the cargo area and walkways should be grounded with passable flooring or surface and to be kept in good condition and adequate lightened. Working in confined spaces such as ship's hold, warehouses, silos and bins conceals potential hazards for lack of oxygen or releasing of toxic and flammable from some materials. If the human work in confined spaced can not be avoided it has to be assured good ventilation, using of respiratory protective equipment and rescue and emergency arrangements. Dusty areas effects mostly on the humans lungs, but in cargoes such as grains and pulses the dust may include contaminants. Preventing exposure, unless making of tasks to reduce of the amount of dust generated and using of respiratory protective equipment, may include suppressing of dust with sprays of water or other binding agents and providing of suitable dust-filtration system by handling of dusty cargoes.

3. REQUIREMENTS TO THE PORT STRUCTURE

The design strength of materials used for port structures must be carefully determinate and also the consequence of damage must be taken into account. The values of material factors have to assure a necessary level of safety to the purpose of maritime structure in order to minimize risks for injury of people and damages to the maritime environment.

To prevent overloading of the berth structure the permissible load capacity should be marked in appropriate port documentations. The loading capacity mainly depends on type of transport means operating the berth. Some of recommended values on safe-bearing capacity for different type of transport means and cargoes are shown on Table 2 (Thoresen C. A., 2010).

It is strongly recommended that the value for the whole terminal to be the same in order to achieve maximum flexibility in cargo-handling techniques. The requirements for a berth structure should be based on the importance of the berth structure, the acceptable level of risk to life safety, the port operations, etc. The weight of the fill behind the berth structure has to serve as stabilizing load, for example on berth anchoring plates and to take into attention the horizontal loading to the berth structure.

The level of operational safety and the quality of the environmental protection is a function of various factors, some of which are: knowledge and skill of personnel; quality of marine structures and technical characteristic of port facilities; administrative and organizational arrangement of duties; stages of the operational processes; and possibility of the management for general improving of port safety, including navigation and safe access to the port, safety performing of cargo-handling operations in port area.

Table 2: Loading capacity of different transport means and cargoes

Type of transport means and cargoes	Loading [kN/m^2]
Light transport means, small cars	5
Heavy transport means	10
General cargo	20
Palletized general cargo	20-30
Multi-purpose facility	50
Offshore feeder bases	50-200
Heavy vehicles, heavy cranes, crawlers crane, etc. that operate from the berth front and 3 m inboard	60
Heavy vehicles, heavy cranes, crawlers crane, etc. that operate from the berth front and 3 m behind the berth front and further inwards	40-100
Containers: Empty and stacked 4 high Full and stacked 2 high Full and stacked 4 high	 15 35 55
General ro/ro loads	30-50

The risk associated with the industrial activities in port has to be carefully valued and all impacts to be taken into consideration. This assessment should be performed before facilities to start performing of operations preferable still in planning process. In case of need should be carried out significant changes, concerning design or placing of the facilities and also changes in operational technologies.

It is obvious that the human is in the center of safety in general. For increasing of safety and decreasing possibility for accidents the unskilled personnel, which pork in port have to be placed with well-trained and learned staff. The maintenance of port handling equipment is one of the factors affecting of the safety operation in port area and contain performing of appropriate actions based on port procedures and rules, support of passable workshops, equipment, tool and necessary spare parts. These presume the effective working and organized system and control. The design aspect from port structure, having in mind quays and berth places should be based on common and proven design methods and technology, typically for sea building. The construction solutions of berth structures should be easy for construction and implementation and to have a possibility for easy adaptation of the equipment and port facilities. Experience shows that maintenance of port structure improves by innovation of modern sophisticated technical and technological solutions.

During then lifetime of the berth structure can be occurs following three conditions:

- Operational conditions provide normal vessel's berthing and fulfilling of load and discharge operations. Due to a safety reason and avoiding of berth structure destroying the maximum acceptable approach ship's velocity should be no more than 2/3 of the calculated approach velocity, which is safety and could not cause damage to the berth structure.

- Accidental conditions may happen during berthing and unberthing of the vessel. In this respect the means of fenders is to take the expected pressure and ferroconcrete construction not to be destroyed under such impact. In accidental condition the concrete structure should be able to resist a horizontal force 20-25 % higher berthing energy than the designed berthing energy in the operational condition without completely destroying of the berth structure. The exact value of ship's approach velocity is very difficult to determinate, but in most cases depends mainly from wind, waves, currents and number of tugs, assisting during berthing operation.

- Catastrophic conditions occur when under vessel's impacts causing completely destroying of the structure. Decreasing the probability on happening of such accidents is possible by taking of following prevention measures: changing sailing routes or imposing restrictions for some kind of vessels.

The requirements for berthing structure should be based on the importance and protection of berth structure, the acceptable level of risk to life safety, the port operations, etc.

4. CONCLUSIONS

The operations bounded up with the environmental conditions during berthing and unberthing the information on tide, current, wind waves, etc. play an essential role together with hydrographical and topographical conditions. These factors play a great role for safety of the ship during berthing and unberthing manoeuvre, as well as for the performing of cargo operations. They should be carefully taken into consideration by planning and evaluation of port structures, such as port sites and layout of berths and breakwaters and other structures.

The measures in navigable waters for controlling, supervising vessels traffic and the same time for protecting navigation and maritime environment should include reporting and operating requirements, surveillance and communication systems, routing systems and fairways. Every port shall fully conform to the appropriate vessels, which normally operate in the port area. The established port and waterway safety program have to control vessel traffic area and to determine risks for hazardous or reduced visibility, adverse weather, vessel congestion or other hazardous circumstances. In order to provide safe access routes for the movement of vessel traffic proceeding to or from ports the necessary fairways and traffic separation schemes for vessel's operating in territorial sea water have to be marked.

Determination and assessment of safety need following navigation information: 1) The hydrographic information, including actual charts, tidal information and supplementary information, especially warnings on recently identified navigation hazards, such as reduction in the depth of water below the chart datum; 2) Information about general conditions, including wind, tide, wave height and other factors liable to be affected by weather and the way of port is used; 3) Working in port area, which could interference with navigation such as dredgers and other craft machines.

Safety operational plans and standards at port land area should provide:

1) identifying of hazards, keeping of risk on low level and in fully conformity with health and safety legislation frames;

2) procedures for technology actions in load and discharge process and as a consequence determination of safety and healthy work with all port facilities; design of policy of relevant technical maintenance to the port devices and mechanisms, planning of periodical repairs and supplying with spare parts.

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THE PERCEPTIONS OF RESPONSIBLE TURKISH OFFICERS FOR INFIRMARY OF THEIR PROBLEM SOLVING ABILITIES

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Comparing to all assigned jobs or work to earn a descent income, money, then no other professions that are more risky compare to seafarers. For we know that all of the jobs or works are all risky too but a seafarer is the most risky profession of all. After graduation from own school, many officers assigned for health officers on board although lack of experience. The aim of the study is to determine the perceptions of responsible Turkish officers for infirmary of their problem solving abilities' level and to find out whether their perceptions differ according to age, gender, marital status, school graduated, competency level, experience and additional health training. In this study survey (questionnaire) method was used. Problem solving inventory (PSI) which was developed by Heppner and Petersen in 1982 and in 1993 PSI was realigned in Turkish Version by Sahin and Sahin was filled to the officers by their companies which they work as an officer. Frequency tables, descriptive statistics, reliability analysis, Kolmogorov - Smirnov Z test, single direction variance analysis (ANOVA), LSD test and independent sample t test are used in the analyses of data.

Keywords: Problem Solving Inventory, Responsible Officer for Infirmary, STCW Code.

1. INTRODUCTION

Seafaring has always been a dangerous occupation. Long voyages, extreme weather conditions, illnesses and accidents can take a heavy toll on the health of crew members. Not only are they exposed to greater risk, seafarers are also isolated from the usual sources of medical care and assistance available to people on shore.

World Health Organizations has consistently strived to improve the health of people at their place of work. When people also live in their work environment – as seafarers must – they face particular risks to their health. It is important to view a ship's medical facility as an infirmary and not as a hospital. Although most of the medical conditions that arise aboard ship can be treated as they would be at an ambulatory care centre at home, more severe problems may require the patient to be treated in a fully staffed and equipped land-based hospital after stabilization on the ship.This study is cover the methodology of the project and the results of the questionnaire study about the perceptions of responsible Turkish officers for infirmary of their problem solving abilities.

1.1. Occupational health and safety

Occupational health in shipping industry covers a greater part of precautionary measures of the health care for seafarers. Health risks due to exposure to conditions of work and life environment, and health requirements for performing jobs and working tasks related to life and work on board, depend on type of the vessel and area of navigation, on specificity of services and practices on board, on type of operations, on specificity of alliance of ship-owners, correspondents and workmen. According to the all these information health hazards on ships which are faced seafarers are; Dangers from living environment, Mechanical dangers, Dangers from electric power, Thermal dangers, Noise, Chemical dangers, Sanitary dangers, Radiation dangers, Violation and Physical work (Nicolic, 2010: 2).

Types of injury that were reported/recorded in the Maritime Administration and companies' databases were shown as Table 1. Although some similarities can be seen in the patterns of reported/recorded injury types between the Maritime Administrations and the companies data sets, with "strains, sprains, and twists", and to some extent "cut or piercing" making up a large proportion of injuries, there are also many differences (Bailey et al., 2010).

Table 1: Injuries Recorded in the Maritime Administration and Companies' Datasets.

Maritime Administrations		Companies	
Injury	%	Injury	%
Strain, sprain or twist	20,4	Striking injury	24,4
Break or Fracture	18,3	Strain, sprain or twist	19,7
Bruising	16,0	Cut or piercing injury	14,1
Fatality	15,8	Crush or trap injury	8,5
Cut or piercing injury	11,5	Missing data	7,2
Missing data	6,4	Foreign body in eye / body	6,4
Burn	4,9	Burn	4,6
Crush or piercing injury	3,8	Bruising	4,1
Graze	1,1	Break or Fracture	3,6
Striking injury	0,9	Aches	2,1
Dislocation	0,3	Graze	2,1
Unconscious	0,3	Exposed to harmful chemical	1,5
Electric Shock	0,2	Dislocation	0,8
Foreign body in eye	0,0	Unconscious	0,5
		Electric shock	0,3
		Fatality	0,3

It may also be the case that certain injuries are more prevalent for certain vessel types, due to the different nature of these vessels, and the cargoes they carry. Table 2 presents the most frequent injury types for the six vessel types identified in part one of this report. These variations in vessel type were only present in the data available from the Maritime Administrations(Bailey et al., 2010: 22).

Table 2: Injuries by Vessel Type within Maritime Administration Dataset Source.

Tankers		Bulk Carriers		Dry Cargo (Non Bulk)	
Injury	**%**	**Injury**	**%**	**Injury**	**%**
Strain, sprain or twist	20,9	Fatality	37,9	Break or Fracture	20,8
Break or Fracture	18,9	Break or Fracture	14,3	Fatality	18,6
Bruising	16,8	Bruising	14,0	Strain, sprain or twist	18,0
Fatality	13,8	Strain, sprain or twist	11,6	Bruising	16,9
Cut or piercing injury	11,8	Cut or piercing injury	8,7	Cut or piercing injury	13,1
Burn	10,6	Burn	7,2	Burn	5,5
Crush or trap injury	3,1	Crush or trap injury	3,6	Crush or trap injury	3,6
Graze	1,8	Graze	0,9	Graze	1,8
Striking injury	1,4	Unconscious	0,9	Striking injury	1,0
Dislocation	0,4	Striking injury	0,6	Unconscious	0,3
Electric Shock	0,3	Foreign body in eye	0,3	Electric Shock	0,2
Unconscious	0,1			Dislocation	0,2
Passenger		**Working Vessel**		**Other**	
Injury	**%**	**Injury**	**%**	**Injury**	**%**
Strain, sprain or twist	25,2	Strain, sprain or twist	24,5	Break or Fracture	24,0
Break or Fracture	18,0	Break or Fracture	19,1	Strain, sprain or twist	23,7
Bruising	16,9	Bruising	18,1	Bruising	14,4
Cut or piercing injury	14,6	Fatality	16,6	Fatality	12,5
Fatality	13,4	Cut or piercing injury	11,4	Cut or piercing injury	11,4
Crush or trap injury	5,1	Crush or trap injury	4,3	Burn	4,6
Burn	4,2	Burn	3,9	Crush or trap injury	4,6
Dislocation	0,9	Graze	0,9	Unconscious	2,5
Striking injury	0,7	Striking injury	0,8	Striking injury	1,1
Graze	0,5	Electric Shock	0,2	Dislocation	0,7
Unconscious	0,4	Dislocation	0,1	Electric Shock	0,4
Electric Shock	0,2	Unconscious	0,1	Graze	0,4

1.2. International organizations and their conventions about seafarers' health and fitness

The World Health Organization (WHO), International Maritime Organization (IMO) and International Labour Organization (ILO) have all introduced international legislation to ensure the health and fitness of seafarers on board global vessels. IMO provides guidance assistance to promote health and safety on board. This includes provisions in the International Convention on Standards of Training,Certification and Watchkeeping (STCW) Convention and medical support provided by national radio medical facilities (ISF, 2012).

The Convention states that ships carrying 100 or more persons and ordinarily engaged on international voyages of more than 3 days' duration shall carry a qualified medical doctor who is responsible for providing medical care. Ships which do not carry a medical doctor shall be required to have either at least one seafarer on board who is in charge of medical care and administering medicine as part of their regular duties or at least one seafarer on board competent to provide medical first aid. Persons in charge of medical care on board who are not medical doctors shall have satisfactorily completed training in medical care that meets the requirements of the STCW for Seafarers (IMO, 1995: 106-128).

2. AN ANALYSES OF PSI: CASE OF THE PERCEPTIONS OF RESPONSIBLE TURKISH OFFICERS FOR INFIRMARY

The aim of the study is to analyses the perceptions of Turkish officers who responsible for infirmary and treatment of patients on board. In this study, quantitative and qualitative research methods were both used to analyses and collecting data. As shown Figure 1, first step of model of the study is defining variables by collecting data via personal interview and literature reviews. Second step is questionnaire development with data obtained from second hand sources.

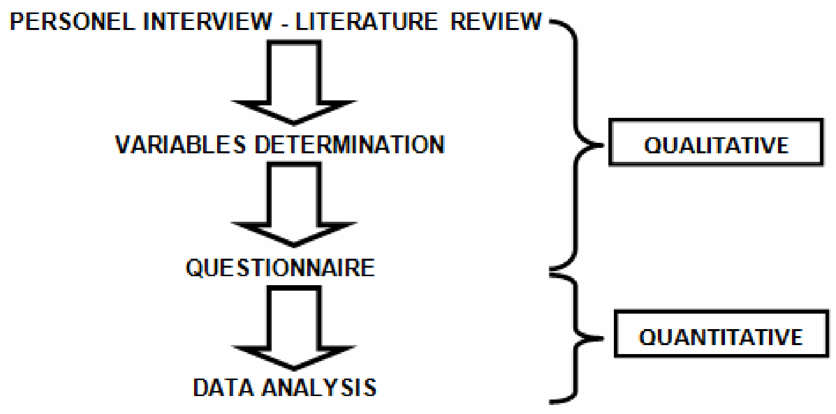

Fig. 1. Model of the Study

2.1. Data collection

The data collection instruments of the study are “Personal Information Form” and “Problem Solving Inventory”. Personal Information Form was developed by the researchers. There were demographic questions to gain better picture of sample. Participants were asked their age, gender, marital status, school graduated, competency level, experience and additional health training.

The problem-solving appraisal measurement tool utilized was the Problem Solving Inventory, developed by Heppner and Petersen in 1982. Problem solving inventory was realigned to Turkish version in 1993 by Nail Sahin and Nesrin H. Sahin (Sahin et al, 1993). The PSI is a self-rating questionnaire that “assesses perceptions of one’s problem solving ability as well as behaviors and attitudes associated with problem-solving style”. The PSI does not measure actual problem-solving skills, only individuals’ perceptions of problem-solving beliefs and style. It consists of 35 items (including 3 filler items). Participants responded to items using a 6-point Likert scale ranging from strongly agree (1) to strongly disagree (6). Range of the score is between 32-192. The total score for the instrument measures total self-appraised problem-solving ability.

A low score on the PSI indicates a perceived effective problem solving ability. The PSI is scored such that a decrease in the score means that an increase in self-assessed problem solving ability occurred (Huang, 2005: 10-11).

2.2. Population and sample

The population of this study is responsible Turkish officers for infirmary. The number of this population is approximately 4500. The sample of this study is 86 responsible Turkish officers for infirmary who works for Kıran Shipping, IDC Shipping, Net Shipping, Besiktaş Shipping, Dryfleet Ship Management, Konvoy Shipping, Nemtas Shipping and Mardas Shipping. The population of the study was shown in Table 3 as below:

Table 3: Population of the Study

Company	Number of Ship (Turkish Crew)	Number of PSI
Besiktas Shipping	18	6
Chem-Dryfleet Shipping	22	13
IDC Shipping	4	4
Kıran Shipping	23	25
Konvoy Shipping	3	12
Mardas	6	15
Nemtas Shipping	4	3
Net Shipping	9	8
TOTAL	**90**	**86**

3. ANALYSES AND FINDINGS

The statistical solutions of the data have been tested by the 16.0 version of SPSS package program. Frequency tables, descriptive statistics, reliability analysis, Kolmogorov - Smirnov Z test, single direction variance analysis (ANOVA), LSD test and independent sample t-test are used in the analyses of data.The PSI is comprised of three subscales (Heppner and Petersen, 1981: 5); Problem-Solving Confidence (PSC; 11 items) measures the level of self-assurance while engaging in problem-solving activities; Approach-Avoidance Style (AAS; 16 items) measures the tendency to avoid or approach various problem-solving activities; and Personal Control (PC; 5 items) assesses the belief that one is in control of emotions and behaviors while engaged in problem-solving activities (Belter, 2008: 32-33).

Table 4: Cronbach's Alpha Value of the Study

Cronbach's Alpha	Number of Items
0.845	32

Problem solving scale and applied reliability analysis in respect to its sub-dimension (PSC, Approach-Avoidance Style and Personal Control) is acquired as Table 4. According to table, the Alpha value is % 84.5. On this basis we can say that scale is reliable.

Table 5: Kolmogorov-Smirnov Z Test Result of the Study

	Problem Solving Ability
N	86
Kolmogorov-Smirnov Z	1.176
p	0.126

In order to determine the normality research techniques will use on data set analysis, closeness in between normal distribution and data set is tested. According to test results, it is determined that data set has a normal distribution ($p > 0.05$). In this context parametric techniques are used in the next steps. After the reliability analysis and Kolmogorv-Smirnov Z test, frequency analysis of demographic characteristics of the participants was made. Also frequency analysis of demographic characteristics of the participants was shown as Table 6. When the participants are observed according to demographic characteristics, these results are seen;

- % 94.2 of participants are male, % 5.8 are female,
- % 40.7 are in between 26-28 age range,
- % 74.4 are single,
- % 66.3 graduated from faculty,
- % 88.4 unlimited watchkeeping officer,
- % 53.5 work between1-3 years,
- % 74.4 is not taking additional health training.

Table 6: Frequency Analysis of Demographic Characteristics of the Participants

Gender	**f**	**Percent (%)**
Male	81	94.2
Female	5	5.8
Age	**f**	**Percent (%)**
20-22	8	9.3
23-25	24	27.9
26-28	35	40.7
29 and above	19	22.1
Marital Status	**f**	**Percent (%)**
Married	22	25.6
Single	64	74.4
Graduated School	**f**	**Percent (%)**
Faculty (4 years)	57	66.3
High School	0	0
Vocational Training School	7	8.1
Course (Ekol, Tüdev, etc.)	21	24.4
Others	0	0
Competency Level	**f**	**Percent (%)**
Ocean Going Watchkeeping Officer	76	88.4
Restricted Watchkeeping Officer	1	1.2
Watchkeeping Officer	9	10.4
Experience	**f**	**Percent (%)**
1-3 Years	46	53.5
4-5 Years	27	31.4
6 Years and above	13	15.1
Additional Health Training	**f**	**Percent (%)**
Yes	22	25.6
No	64	74.4

A low score on the PSI indicates a perceived effective problem solving ability. The PSI is scored such that a decrease in the score means that an increase in self-assessed problem solving ability occurred (Huang, 2005: 10-11). Range scores of problem solving inventory changes between 32-192. Between 32-85.3 scores are high level, 85.4-138.7 scores are middle and 138.8-192 scores are low level (Eser et al., 2009: 13).

Table 7: Level of the Participants of This Study

	N	Min.	Max	Mean	SD.
Problem Solving Abilities	86	48.00	115.00	75.2791	15.80890

The level of the participants of this study was shown as Table 7. According to Table minimum score is 48 and maximum score is 115. The mean score of the participants is 75.27 and it shows level of problem solving abilities of the participants are high so they have effective problem solving ability.

4. TESTS OF HYPOTHESES

Differences the perceptions of responsible Turkish officers for infirmary of their problem solving skills according to the variables were shown as tables. At this stage, the research hypotheses will be tested in the study mentioned in the previous section.

H1: According to problem solving ability, there is a significant difference in between different age participants.
H2: According to problem solving ability, there is a significant difference in between female and male participants.
H3: According to problem solving ability, there is a significant difference in between married and single participants.
H4: According to problem solving ability, there is a significant difference in between different educational levels.
H5: According to problem solving ability, there is a significant difference in between different competence levels.
H6: According to problem solving ability, there is a significant difference in between different experiences.
H7: According to problem solving ability, there is a significant difference in between participants which are educated in respect to health and not educated.

Result of ANOVA test determines there was no significant difference respect to approach-avoidance and level of problem solving abilities between participants from different age groups ($p > 0.05$). Significant difference is found in respect to problem solving confidence and personal control ($p < 0.05$). Differences according to the age were shown as Table 8.

Table 8: Test of Hypothesis H1 (Comparisons between age groups)

	Age	N	Mean	SD.	F	p
Problem Solving Confidence	20-22	8	28.7500	11.56040	3.020	0.034
	23-25	24	21.4583	6.14307		
	26-28	35	20.8571	6.87341		
	29 and +	19	20.7895	5.61327		

Approach-Avoidance	20-22	8	43.6250	7.30826	0.813	0.490
	23-25	24	38.4167	9.49103		
	26-28	35	38.8857	6.99484		
	29 and +	19	38.8421	10.14486		
Personal Control	20-22	8	20.5000	4.50397	3.493	0.019
	23-25	24	17.7083	3.25014		
	26-28	35	18.1429	3.09784		
	29 and +	19	16.2632	2.68415		
Problem Solving Ability	20-22	8	89.5000	20.45902	2.526	0.063
	23-25	24	73.9583	15.64964		
	26-28	35	74.1143	14.64837		
	29 and +	19	73.1053	14.11813		

To determine between which groups subject difference takes place, LSD test is applied by pair wise comparison and the results are shown as Table 9. According to results of test;

- Self-perception of inadequacy level about problem solving Confidence of 20-22 age groups is higher than 23 ages and above.
- Self-perception of inadequacy level about personal control of 29 age and above participants are lower than 20-22 and 26-28 age groups' participants

Table 9: LSD Test's Result for Hypothesis H1

	Age	**Age**	**Mean difference**	**p**
Problem Solving Confidence	20-22	23-25	7.29167*	0.012
		26-28	7.89286*	0.005
		29 and +	7.96053*	0.008
	23-25	20-22	-7.29167*	0.012
		26-28	0.60119	0.745
		29 and +	0.66886	0.755
	26-28	20-22	-7.89286*	0.005
		23-25	-0.60119	0.745
		29 and +	0.06767	0.973
	29 and +	20-22	-7.96053*	0.008
		23-25	-0.66886	0.755
		26-28	-0.06767	0.973
Personal Control	20-22	23-25	2.79167*	0.036
		26-28	2.35714	0.064
		29 and +	4.23684*	0.002
	23-25	20-22	-2.79167*	0.036
		26-28	-0.43452	0.610
		29 and +	1.44518	0.145
	26-28	20-22	-2.35714	0.064
		23-25	0.43452	0.610
		29 and +	1.87970*	0.043
	29 and +	20-22	-4.23684*	0.002
		23-25	-1.44518	0.145
		26-28	-1.87970*	0.043

As it seen on the t-test table, there is no significant difference in between male and female participants according to approach-avoidance level. On the other hand, there are significant differences on problem solving reliability, personal control, and problem solving ability levels ($p < 0.05$). Differences according to the gender were shown as Table 10.

Table 10: Test of Hypothesis H2 (Comparisons According to Marital Status)

	Gender	N	Mean	SD.	t	p
Problem Solving Confidence	Male	81	22.1481	7.22342	2.135	0.036
	Female	5	15.2000	1.92354		
Approach-Avoidance	Male	81	39.5309	8.42331	1.526	0.131
	Female	5	33.6000	8.61974		
Personal Control	Male	81	18.0741	3.27406	2.895	0.005
	Female	5	13.8000	1.09545		
Problem Solving Ability	Male	81	76.1975	15.69189	2.218	0.029
	Female	5	60.4000	9.60729		

Level of problem solving confidence, Personal control and problem solving ability of Female participants are better than male participants.

According to other ANOVA or t test results, there is no significant difference ($p > 0.5$) in between different education levels, competency level, duration of the work and status additional health training for all variables (Problem Solving Reliability, Approach-Avoidance, Personal Control, Problem Solving Ability).

5. CONCLUSIONS

Occupational health in shipping industry covers a greater part of precautionary measures of the health care for seafarers. The seafarer's profession has been regarded as one of the most dangerous jobs, and people who spend their active lives at sea have been exposed to serious risks which endanger their health and their lives.

According to the analysis mean score of 86 officers is good and it shows level of problem solving abilities of the participants is high so they have effective problem solving ability. According to the variables the officers of 20-22 age groups are worse than other age groups. Also male officers' perceptions of problem solving ability are worse than female officers' perceptions of problem solving ability. Despite results of tests are said that there is no any significant difference between other variables when comprise the single officers' score is better than married officers' score, the score of the officers who graduated faculty is better than the score of the officers who graduated high school and vocational training school, the score of the officers whose competency level is ocean going watchkeeping officer is better than the score of the officers whose competency level is restricted watchkeeping officer and watchkeeping officer and the score of the officer whose experience 4-5 years is better than the score of the officers whose experience 1-3 years and 6 years and above.

Seafarer's profession has a lot of difficult conditions. On board all crews have to be ready to everything and of course attention is very important. Sometimes absence of these seafarers faces some health problems on board so the perceptions of responsible Turkish officers for infirmary have to be high. Analysis show us the perceptions of responsible Turkish officers for infirmary are high and they have effective problem solving ability. Also high total working period on board and high experience bring high perceptions of problem solving ability. In my opinion seafarer's profession may be difficult for women so only the self confident women work at this job. This opinion explains that why the female officers' perceptions of problem solving ability is better than male officers' perceptions of problem solving ability. Also faculties have more quality education than courses or vocational training schools so it shows us why the score of the officers who graduated faculty is better than the score of the officers who graduate courses or vocational training schools. Lastly good and quality education, long trainings and work hard brings competency level of ocean going watchkeeping officer so these explain why the score of the officers whose competency level is ocean going watchkeeping officer is better than the score of the officers whose competency level is restricted watchkeeping officer and watchkeeping officer.

In conclusion our recommendations based on this survey, more female officers should work on board. Also courses and vocational training schools' education level should be increased as good as faculties' education level. Training period should be more than now because experience is very important for perceptions of problem solving ability. Courses should have some education standards because one of their graduate's competency level is watchkeeping officers but one year later their graduated competency level is ocean going watchkeeping officers and one year later again change the competency level. Despite change of competency level their education standards don't change a lot so this situation should be fixed.

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ENERGY CAPTURE IN THE GRAVITATIONAL VORTEX WATER FLOW

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The theoretical and experimental study of a new type of micro hydropower converter is realized. The converter may be used for energy conversion of river water with small heads and coastal currents into mechanical work by local restructuring of water flow through a vertical conical channel in spiral form of gravitational vortex. In this vortex, at different heights of the conical channel, are positioned the rotor blades of the turbine with different values of specific speed. The characteristics of the gravitational vortex flow of water through the conical channel, the speed and the power characteristics of the micro hydropower converter were investigated and experimentally validated.

***Keywords**:* micro hydropower, gravitational vortex, hydro turbine, turbine stage, specific speed

1. INTRODUCTION

In Europe, more than 70% of the output of the theoretically available hydropower capabilities are fully developed (Giesecke & Mosonyi, 2005). The development of hydropower with more than 1 MW installed capacity is as far as possible completed (Wieman et al., 2007). The range of of small-scale hydropower from 100 up to 1000 kW with very low head differences from 0.50 m up to 2.00 m is a promising niche for the future use, though this bracket of hydropower is generallyconsidered to be not exploitable. For the explotation of the currently unused hydropower potential, a large number of energy converters ave been proposed (Wieman et al., 2007): Gorlov-Turbine, Davis-Turbine, Underwater Electric Kite (UEW), Kinetic Hydro Power System (KHPS), HydroVenturi technologies under development, Transverpello, HydroPowerLens, Stream Wheel technologies at laboratory stage and Gravitational Vortex Converter (Zötloterer, 2004), Aniprop, Roue Barrage, Rotary Hydraulic Pressure Machine (RHPM) technologies at prototype stage.

In this paper is studied a new type of gravitational vortex converter (Marian et al., 2009), which differs from known converter (Zötloterer, 2004) by those that the water flows through a vertical conical channel and, at different heights of the conical channel are positioned the turbine stages with different specific speed.

2. THE MICRO HYDROPOWER CONVERTER CONCEPT

The proposed micro hydropower converter (Marian et al., 2009) developed a new technology for converting hydraulic energy of small rivers and coastal currents into mechanical work due to local restructuring of water flow in spiral flow through a conical channel as a gravitational vortex. In the vortex thus formed, at the different heights of the conical channel are positioned the stages of rotor blades with different diameters. The specific speed of turbine stage varies depending on its position on the height of the conical channel and on interaction with other turbine stages.

It is known that in the case of a high power HPP, increasing of hydro turbine output by 1% increases the power of several MW. Under the new concept solves the problem of increasing the efficiency of hydraulic flow energy conversion into electricity by using a hydraulic turbine with stages, which specific speeds are different. Thus, the small hydropower converter from Figure 1, consists of a foundation ashore in the form of a cylindrical concrete spiral cases with tangential inlet connection, which is deflected a part of the river. The spiral chamber is equipped with a fixed Fink blade unit director with adjustable tilt. Under the spiral chamber is placed a conical channel for the formation of the water flow as a gravitational vortex. In the bottom of the conical channel is made a central drainage hole, positioned over a channel of escape. Between the central drainage hole of the chamber and the running channel is connected to a draft tube in the elbow.

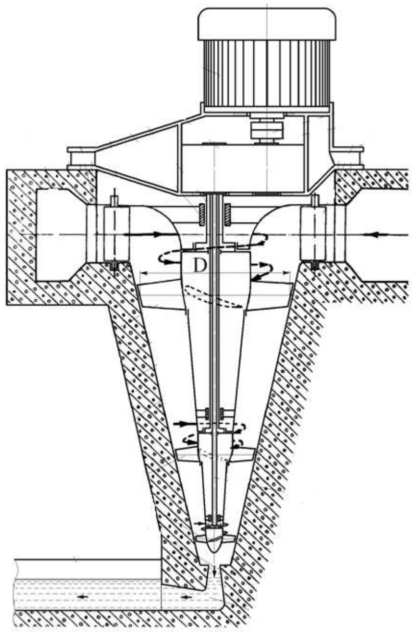

Fig. 1. Section through the micro hydropower converter using gravitational vortex

In the center of the spiral chamber and the conical channel is positioned the hydraulic turbine with vertical shaft, kinematic connected by a mechanism of angular velocity reduction and multiplication gear with electric generator. The hydraulic rotor is performed in stages with characteristic diameters of mobile blades which decreases along the entrance to the chamber drain hole directly proportional to decreasing cross-sectional diameter of the chamber in which are located. Each stage of the rotor is mounted on its axis of rotation. The axis are assembled telescopic and are coupled to respective driving gears of the mechanism of reduction and multiplication. The types of blades used in each stage are chosen based on its specific speed. For water flow in the gravitational vortex the most indicated are the helical turbine stages with the hydrofoil profile.

Can be used Francis turbine stages with the form according to specific speed. Due to large variation of the peripheral velocity $v = \omega \cdot r$ along the blade, is necessary to twist the blade.

The mechanism of speed reduction and multiplication gear consist of a number of pairs of gears engaged with each other, equal to the number of stages of the turbine, which, depending on turbine gear rpm, some pairs are used to reduce angular velocity and othersto multiply up to the nominal velocity of the electric generator.

3. THEORETICAL ANALYSIS

3.1. Flow characteristics

The calculation scheme of the studied micro hydropower converter (Marian et al., 2009) is illustrated by Figure 2. The device comprises a water supply channel (CA), positioned in a direction tangential to the wicket gate (AD).

The latter is directly connected to the vertical conical channel (CC) provided with a telescopic shafts one for each of turbine stages (T_1, T_2 and T_3), rotating individually and positioned at different heights of conical channel. Water enters and exits from the micro hydropower converter at a constant discharge (sink strength) Q. The wicket gate induces a rotation movement to the entering water with of a vortex strength Γ and angular velocity ω. All turbines stages T_1, T_2 and T_3 will be characterized by various angular speeds, namely ω_1, ω_2 and ω_3, respectively.

The water discharge, defined as $Q = \mu S\sqrt{2gH}$, will depend on the area of the drain section (S) of the conical channel, the height of the available water head (H) and the rate of flow coefficient (μ).

In the absence of swirl the rate of flow coefficient will be expressed in terms of $\mu_0 = \varepsilon(\alpha)\cdot\varphi(Q,\alpha)$,where:

$\varepsilon(\alpha) = 1 - 0.001\cdot\alpha^{1.28}$ is the coefficient of the strangulation of water jet in the drain hole of the conical channel; $\varphi(Q,\alpha) = 1/\sqrt{1+\varsigma(Q,\alpha)}$ -coefficient of velocity; $\varsigma(Q,\alpha) = \lambda(Q)\left[1-(d/D)^4\right]/8\cdot tg\alpha$ - coefficient of local hydraulic losses of the drain hole of the conical channel; $\lambda(Q) = 0.02 + 0.0018/\sqrt{8\cdot Q/(D+d)\cdot\pi}$ - coefficient of linear hydraulic losses of the conical channel (Alitshuli,1976).

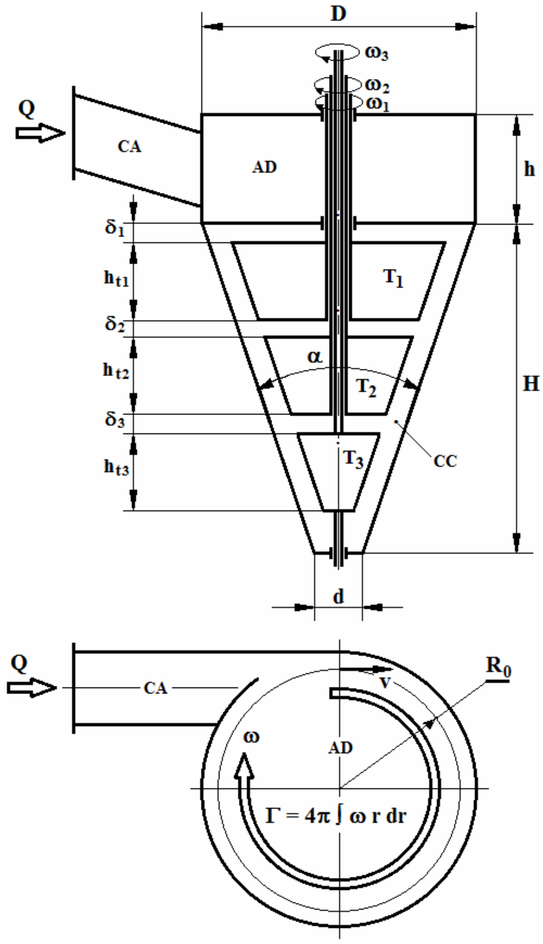

Fig. 2. The calculation cheme of the micro hidropower plant with gravitational vortex

At swirl-like water flow, the rate of flow coefficient of the conical channel depends on Froude's (Fr), Reynolds's (Re) and Weber's (We) numbers, along with the vortex dimensionless strength $(\Gamma *)$ and geometric simplex $(R*)$ (Alitshuli,1976):

$$\mathrm{Fr} = \frac{H}{d};\quad \mathrm{Re} = \frac{d\sqrt{2g(H+h)}}{\upsilon};\quad \mathrm{We} = \frac{2g(H+h)d\rho}{\sigma};\quad \Gamma * = \frac{2\pi R_0 V}{d\sqrt{2g(H+h)}};\quad \mathrm{R}* = \frac{R_0}{d}. \tag{1}$$

For $\mathrm{Fr} \geq 2.5$, $\mathrm{Re} \geq 30000$ and, the rate of flow coefficient μ does not depend on Fr, Re and We. In this case:

$$\mu_1 = 0.795 - 0.256\cdot\frac{\Gamma *}{\sqrt{2}\cdot\pi\cdot\mathrm{R}*}\cdot\left(\frac{1}{\mathrm{R}*} + 4\cdot\mathrm{R}*\right) \tag{2}$$

The general equation, to be experimentally validated for the calculation of the rate of flow coefficient, is expressed by equation:

$$\mu = \mu_0 - (\mu_0 - \mu_1) \cdot f(Fr, \mathrm{Re}, We). \tag{3}$$

where the function $f(Fr, \mathrm{Re}, We)$ will be determined experimentally.

The swallowing ability which is a constant for the tested turbine will be calculated using equation:

$$Q_1 = \mu \cdot \frac{\pi \cdot d^2}{4} \cdot \sqrt{2}\,. \tag{4}$$

3.2. Speed characteristics

From Bernoulli's equation, the different angular velosities ω_1, ω_2 and ω_3 involved in the respective flow steps of water starting from the supply channel CA up to turbine T_1, turbine T_2, turbine T_3 were expressed equation:

$$\omega_i = \frac{2g\left(H_i - H_i^*\right) \cdot \eta_{hi}}{D_{t1i} \cdot c_{1i} \cdot \cos\alpha_{1i} - D_{t2i} \cdot c_{2i} \cdot \cos\alpha_{2i}}\,. \tag{5}$$

where H_i is the heads from out of turbine T_1, [m]; i=1,2,3; H_i^* - share of available head of water H_i converted into mechanical work by the turbine stages pozitioned above of the turbine stage T_i: $H_1^* = 0$; $H_2^* = H_1 \cdot \eta_{h1}$; $H_3^* = H_1 \cdot \eta_{h1} + (H_2 - H_1 \cdot \eta_{h1}) \cdot \eta_{h2}$; $\cdot\eta_{hi}$ - hydraulic efficiency of the respective turbine stage; D_{t1i} and D_{t2i} - turbine rotor diameter at the entrance and at the exit from the turbine T_i; α_{1i} and α_{2i} - the angles between absolute velocity vectors $\mathbf{c}_{1i}$ and the blade velocity vectors $\mathbf{v}_{2i}$ at the entrance and at the exit of the turbine stage T_i.

The nominal speed and the specific speed of the turbine stage were calculated with the relations $n_{nom.i} = 30 \cdot \omega_i / \pi$ $\quad n_{s.i} = 0.645 \cdot n_{nom.i} \cdot \sqrt{Q \cdot H_i \cdot g \cdot \eta_{nom.i} / \sqrt{H_i \cdot g}} \Big/ H_i \cdot g$.

Thus, the speed characteristics of the micro hydropower converter will be determined using equations:

$$M_i(n_i) = M_{\max.i} \cdot \left[1 - \left(\frac{n_i}{n_{r.i}}\right)^2\right]; \tag{6}$$

$$P_i(n_i) = M_i(n_i) \cdot \frac{\pi \cdot n_i}{30}; \tag{7}$$

$$\eta_i(n_i) = \frac{P_i(n_i)}{\rho \cdot Q \cdot \left(H_i - H_i^*\right) \cdot g}\,, \tag{8}$$

where M_i is the torque at the shaft of the turbine stage, [N·m]; n_i - the speed of turbine stage, [rot/min]; $n_{r.i} = \left[\left(n_s^2 / \left(5 \cdot 10^4 + n_s^2\right)\right) + 1.5\right] \cdot n_{nom.i}$ - the runaway speed of the turbine stage, [rot/min]; P_i - the power at the turbine coupling, [W]; ρ - water density, [kg/m^3]; Q - discharge, processed by the turbine stage, [m^3/s]; H_i - the head of turbine stage, [m]; g - the gravitational acceleration (g = 9.81 m/s^2); η_i - the overall efficiency of the turbine stage; $M_{\max.i} = 30 \cdot \rho \cdot Q \cdot \left(H_i - H_i^*\right) \cdot g \cdot \eta_{nom.i} / \pi \cdot n_{nom.i} \cdot \left[1 - \left(n_{nom.i} / n_{ri}\right)^2\right]$ - the maximum torque at the shaft turbine stage at zero speed of the turbine, [N·m]; $\eta_{nom.i}$ - the nominal efficiency of the turbine stage.

3.3. Power characteristics

The dependence of the stage efficiency and water flow on the turbine power was determined by equations:

$$\eta_i(P_i) = \left(\frac{P_i}{P_{opt.i}}\right)^{0.8} \cdot \left[2 - \left(\frac{P_i}{P_{opt.i}}\right)^{0.8}\right] \cdot \eta_{\max.i} \cdot ; \tag{9}$$

$$Q_i(P_i) = \frac{P_i}{\rho \cdot Q_i \cdot \left(H_i - H_i^*\right) \cdot g \cdot \eta_i(P_i)}. \tag{10}$$

where $\eta_{\max.i} = 2 \cdot \pi \cdot M_{\max.i} \cdot n_{r.i} / 90 \cdot \sqrt{3} \cdot \rho \cdot Q \cdot \left(H_i - H_i^*\right) \cdot g$ is the maximum efficiency of the turbine; $P_{opt.i} = 2 \cdot \pi \cdot M_{\max.i} \cdot n_{oi} / 90 \cdot \sqrt{3}$ - optimal power at turbine coupling, [W].

4. EXPERIMENTAL EQUIPMENT

The experimental device was made using two tanks connected into a closed circuit provided with a pump, between which was interleaved the laboratory physical model of the micro hydropower converter. The conical channel has two diameters, namely D = 0.12 m, d = 0.018 m and four conical sections with respective heights at 0.10, 0.15, 0.20 and 0.25 m and opening angles at α: 54.04^0; 37.56^0; 28.61^0; 23.06^0. Water flow was determined by volumetric method and was adjusted with a tap. In the upper part of the telescopic rotation axes, a disc with variable diameter is positioned. This disc supports sensitive lines glued for laser readers of three UT 371-type tachometers. The rotation axes are provided with was adjustable brakes with reading device for measuring the resistance moments (M_i) applied. The latter varies from zero to its maximum value when speed n_i=0.

According to the experiment, a single turbine stage (usually T_3), two or three turbines could be mounted at the required heights within the conical channel. Each turbine rotor consists of four blades (profile type W-Wirbel-Kraftwerk (Zötloterer, 2008)). Such as device was designed to allow easy and accurate measurements of the experimental characteristics $Q_1(Q)$, $Q_1(\alpha)$, $M_i(n_i)$, $P_i(n_i)$, $\eta_i(n_i)$ and $Q_i(P_i)$. These data will be used to validate equations (2), (6) - (10).

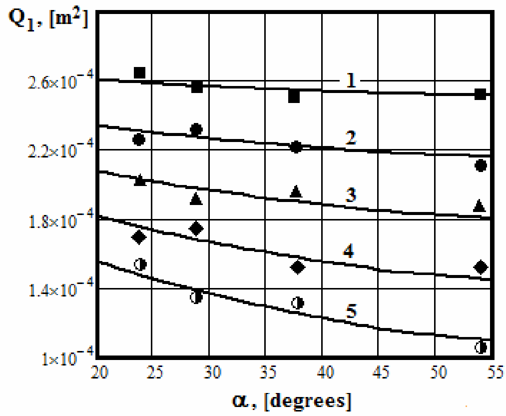

Fig. 3. Swallowing capacity Q_1 of the turbine versus angle α from the vertex of conical channel:

points-experiment, continuous curves drawn according to formulas (1)-(4); Q,[m^3/s]: 1-$1 \cdot 10^{-4}$; 2-$2 \cdot 10^{-4}$; 3-$3 \cdot 10^{-4}$; 4-$4 \cdot 10^{-4}$; 5-$5 \cdot 10^{-4}$

5. RESULTS

Variation of the water throughput (Q) between $1 \cdot 10^{-5}$ up to $5 \cdot 10^{-4}$ $[m/s]$ allowed plotting the evolution of the characteristic $Q_1(\alpha)$ versus the inclination angle (Figure 3). The general tendency is that increasing angle induced a decrease of the swallowing capacity of turbine T_1. This effect was more accentuated with increasing Q. Equation (3) provides a better approximation of the theoretical results by the experimental function *f*(Fr, Re, We) given by equation:

$$f(\mathrm{Fr},\mathrm{Re},\mathrm{We})=\left(2.3\cdot\mathrm{Fr}^{-1}+0.032\cdot\mathrm{Fr}\right)\cdot\left(2.8\cdot10^{4}\cdot\mathrm{Re}^{-1}+2.21\cdot10^{-6}\cdot\mathrm{Re}\right)\cdot$$
$$\cdot\left(235\cdot\mathrm{We}^{-1}+2.4\cdot10^{-4}\cdot\mathrm{We}\right)\cdot\exp\left(-\frac{2.5-\mathrm{Fr}}{\mathrm{Fr}}\right)\cdot\exp\left(-\frac{3\cdot10^{4}-\mathrm{Re}}{\mathrm{Re}}\right)\cdot\exp\left(-\frac{250-\mathrm{We}}{\mathrm{We}}\right)\cdot \quad (11)$$

In Figure 4 are presented the speed characteristics of the three turbines T_1, T_2 and T_3. In dimensionless coordinates these diagramms coincide for all stages of turbine, but with small increasing of the maximum efficiency of turbine stage T_3. In dimensional values, the

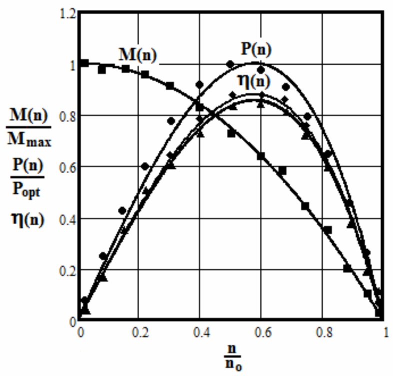

Fig. 4. Speed characteristics of micro hydropower plant with gravitational vortex:

points-experiment, continuous curves drawn according to formulas (6)-(8)

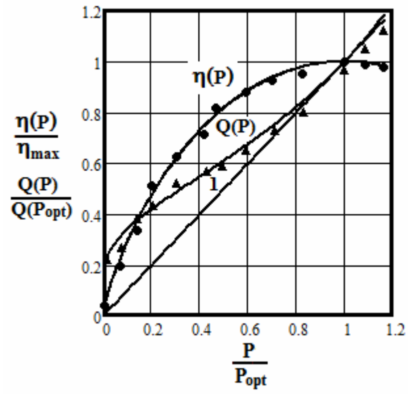

Fig. 5. Power caracteristics:

points-experimental data continuous curves drawn according to formulas (9) and (10); 1- characteristics calculation Q(P) for η=const.

maximum moment M_{max} was found to decrease from turbine T_3 to T_1. The specific speed from turbine T_1 to T_3 decrease by a factor of at least two times. The highest power extracted was minimum at turbine T_2, maximum at turbine T_3 and intermediate at turbine T_1. The maximum efficiency showed values of 0.88 for turbine T_3 and 0.85 for the two others.
For the case of a single turbine with increasing distance from the entrance section in the conical channel, M_{max} increased up to a maximum, and then decreased. In the meantime, n_{nom} and P_{opt} increased, while η_{max} remains constant. M_{max} increased and n_{nom} decreased with increasing of angle α at the vertex of the cone.

The power characteristics of the turbine are shown in Figure 5. In dimensionless coordinates, these characteristics coincide for all three turbines. It was noticed that the efficiency increases with the power up to a maximum at $P = Popt$, then decreases. The water discharge processed by the turbine is given by the relationship $Q = P/\rho Hg\eta$. For constant efficiency (η), the flow varied linearly with the power (curve 1 in Figure 5). Since η is variable, *Q* varies in a nonlinear way. Curve *Q(P)* did not start from zero, but from a more than 0.2 value of the discarge $Q(P_{opt})$.

These experimental results are in good agreement with those calculated, allowing thereby the validation of the theoretical models examined previously.

6. THE ADVANTAGE OF USING OF THE GRAVITATIONAL VORTEX FOR ENERGY CAPTURE AT LOW WATER HEADS

There are two ways to speed up the water flow successively: acceleration under the gravity action, necessary for operating of wicket gate; acceleration resulting from gravitational vortex formation. In the first case the flow velosity will be determined by the relation:

$$v(\Delta H) = \left(\frac{2 \cdot g \cdot \Delta H}{\xi + 1 + \lambda \cdot \dfrac{\Delta H}{d}} \right)^{0.5} , \qquad (12)$$

in the second case - by formula:

$$v(\Delta H) = v\left(\frac{\Delta H}{n} \right) \cdot \frac{A_0}{A_C} , \qquad (13)$$

where ΔH is the available water head, [m]; ξ - local coefficient of hydraulic losses, λ - Darcy coefficient of linear hydraulic losses; *d* - channel diameter, [m]; n - coefficient of reduction of available water head; $A_0 / A_C \sim (D/d)^2$ - the stream compression in the gravitational vortex.

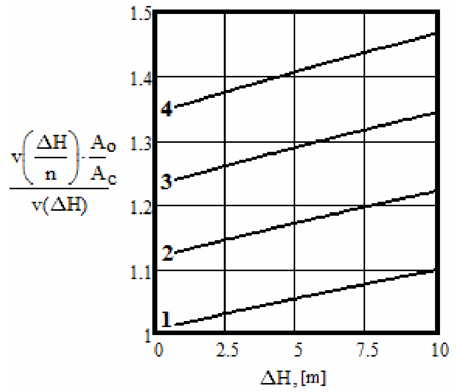

Fig. 6. The effect of flow acceleration in gravitational vortex:

n=5; λ=0.08; ξ=1; A_0/A_C: 1-2.25; 2-2.50; 3-2.75; 4-3.00

In Figure 6 are presented in comparison the graphics for these two cases of which results the advantage of vortex gravitational acceleration using for energy capture from small water heads.

7. COMPARISON WITH OTHER MICROPOWER TECHNOLOGIES

The Table 1 is showing an overview of the most important characteristics of proposed and investigated within this paper multistage gravitation vortex converter (Marian et al.,2009) in comparison with the same ones of examined by Wieman, Muller and Senior modern micro hydropower machines (Wieman et al., 2007).

Table 1: Summary of the some characteristics of new low head energy converters

	Machinery efficiency as quoted by manufac-turer	**Total effici-ency**	**Total efficiency based on experts' estimati-ons**	**Electrical power for Q=2,5 m³/s and H=1,5 m and v=5,4 m/s**	**Investment costs of machinery and electrical components**	**Invest-ment costs of civil engine-ering**	**Specific invest-ment cost per installed kW**	**Fish compati-bility in compari-son with turbines**
Values for the orientation [4]				**37.5 kW**	**112,500 EUR**	**112,500 EUR**	**6,000 EUR**	**0**
Stream Wheels [4]	40%	34%		13 kV	0	-	-	+
Staudruckmaschine [4]	95%	76%	67%	25 kV	0	0	0	+
Roue Barrage [4]	95%	76%	67%	25 kV	0	0	0	+
Aniprop* [4]	59%	50%	12.5%	1.9 kV	0	0	0	+
Transverpello* [4]	44%	37%	5%	0.8 kV	0	0	0	+
HydroPowerLens [4]	25%	21%		8 kV	0	+	+	+
Gorlov-turbine* [4]	45%	33%		5 kV	+	-	0	+
Davis-turbine* [4]	-	-	30%	4.5 kV	+	-	0	+
Hydro Venturi* [4]	30%	20%	10%	1.5 kV	+	-	0	+
UEK* [4]	57%	37%		5.5 kV	+	-	0	+
KHPS* [4]	30%	20%		3 kV	+	-	0	+
Single-stage Gravitation Vortex Converter [5]	80%	52%	35%	13 kV	-	+	0	+
Three-stage Gravitation Vortex Converter [3]	-	93%	-	35 kV	-	+	0	+

Legend: + higher, - lower, 0 similar to value of orientation; *referred to the kinetic energy; all other referred to the potential energy.
**** Efficiency total is calculated with the experts estimation.**

in comparison with the same ones of examined by Wieman, Muller and Senior modern micro hydropower machines (Wieman et al., 2007).

8. CONCLUSIONS

Have been proposed a new type of gravitational vortex converter, which differs from known converter by those that the water flows through a vertical conical channel and, at different heights of the conical channel are positioned the turbine stages with different specific speeds.

Mathematical models were proposed to describe the flow characteristics of a conical turbine stator for water flow in gravitational vortex, speed and power characteristics of a micro hydropower converter that have been validated experimentally. In vortex hydrodynamics, the rate of flow coefficient was found to depend on Froude's, Reynolds' and Weber's factors, along with the dimensionless strength and diameter ratio of the vortex in the wicket gate and drain hole diameter of the conical channel. For $\mathrm{Fr} \geq 2.5$, $\mathrm{Re} > 3 \cdot 10^4$ and $\mathrm{We} > 250$, the rate of flow coefficient did not display any dependence on this three dimensionless numbers. The swallowing capacity of the turbine was found to be affected by increasing of angle from vertex of the conical channel. This effect is more accentuated at higher water discharge.

At concurrent operation of all turbine stages, energy performance of the closer turbine stage to the drain hole of the conical channel are higher, and the intermediate turbine stage lower than the upper stage.

There are two ways to speed up the water flow successively: acceleration under the gravity action, necessary for operating of wicket gate and acceleration resulting from gravitational vortex formation, but the second method is more efficient, even at water heads on 2-5 times lower.

The theoretical estimation and experimental testing of three-stage Gravitational Vortex Converter model showed that the hydraulic efficiency reaches values of 90-95% depending on the dimensions of the conical channel and of the precision taper adjustment of specific speeds of turbine stages to local angular velocity of water.

The high efficiency is explained by loss reduction with high residual fluid velocity after the first turbine stage by the stages positioned at lower levels. Blade profile optimization is necessary in this regard.

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FLOW FIELDS IN THE CONICAL CHANNEL OF MICRO HYDROPOWER CONVERTER IN PRESENCE AND IN ABSENCE OF TURBINE STAGES

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For a new concept of micro hydropower converter with positioned in gravitational vortex flow multistage turbine rotor with different values of specific speed has been modeled the velosity field of water flow through the conical channel in the absence of the turbine stages and was determined the flow structure by the computer simulation in the presence of the turbine stages. In the first case, the stream lines appear as helical spirals. The distributions of circular, radial and axial velocity components in the boundary layer, in the potential flow (zone of the free vortex) and in the forced vortex was determined. In the second case the structure of the water flow is changes with the formation of individual swirls in every area between the blades. The water velocity increases rapidly as proximity to the drain hole and strongly depends on sink and vortex strengths.

***Keywords**:* micro hydropower; free and forced vortices; circular, radial and axial velosities

1. INTRODUCTION

The theory of *rotational flow* of ideal fluid was founded by the three vorticity theorems of Helmholtz (1858), who named such flows as "*vortex motions*." His work opened a brand new field, which was enriched by, among others, Kelvin's (1869) circulation theorem. But the inviscid fluid model on which these theorems are based cannot explain the generation of the vortices and their interaction with solid bodies. The physical theory of vorticity and vortex dynamics is presented systematically by Wu, Ma and Zhou (Wu et al., 2006).

The potential gravitational flowing of a water through a conical funnel-like channel of micro hydropower converter in the absence of turbine stages may be considered as generated by a potential vortex of strength $\Gamma=2\pi rv$ placed along the axis and by a sink of strength *Q* placed at the vertex of the cone.

A particular case for pure sink flow $\Gamma = 0$ was studied by Binnie and Harris (Binnie & Harris, 1950). Another particular case for pure vortex flow Q = 0 was studied by Taylor (Taylor, 1950) and Cooke (Cooke, 1952). The flow forms a boundary layer on the wall of the conical channel. The flow field in the boundary layer develops a velosity component *w* in the direction of the cone generators, whereas the frictionless core, being a pure swirl, possesses only tangential velosity component *v* (Schlichting, 1979). The secondary flow in the boundary layer transports some fluid towards the vertex of the cone.

Particular solution of Euler equations, obtained by Rankine (Wu et al., 2006), describes an axially symmetric vortex flowing, with circular *v*(r), radial *u*(*r*) and axial *w*(*z*) velocity components, directly proportional to radius r, respectively to coordinate z in forsed vortex, and inversely proportional to *r* in free vortex, in which *w*(*z*)=0 (Wu et al., 2006).

The flowing structure becomes more complicated In the presence of turbine stages and in this case the computer simulation is required.

In this paper has been modeled the water flowing through the conical channel in the absence of the turbine stages and was simulated the flowing structure in the presence of the stages.

2. THE WATER FLOWING THROUGH THE CONICAL CHANNEL IN THE ABSENCE OF TURBINE STAGES

We have consider the flowing of incompressible fluid with density ρ through a conical channel generated by a potential vortex of strength $\Gamma=2\pi rv$ placed along the axis and by a sink of strength Q placed ar the vertex of the cone. Geometrical dimensions of the conical channel are given.

We have to determine the distribution of the radial u, the circular (tangential) v and axial w velocity components.

Flowing structure is shown in Figure 1. At walls of cylindrical and conical channels is formed boundary layer of thickness δ. In the center of channel, under the action of centrifugal force generated by vortex rotation, an air cavern is formed. The air and partly the fluid in the immediate vicinity of the surface of the air-water phase separation, are rotated with force, as a solid body with angular velocity ω. The flowing in this area is rotational. Between air cavern and boundary layer, the flowing is potential (irrotational), vortex in this area being free. In the boundary layer the fluid no longer behaves as a ideal fluid, increasing role of influence of viscous forces on the movement.

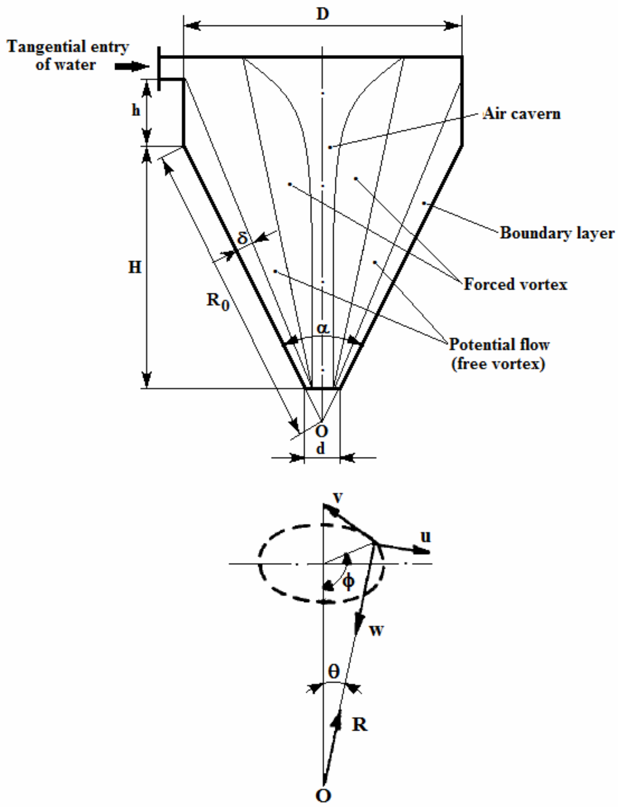

Fig.1. Water flow structure through conical channel in gravitational vortex

2.1. Flow field in the boundary layer

In the boundary layer approximation, the equation Navier-Stokes and continuity equation in sferico-polar coordinates are written in the form (Taylor, 1950):

$$\frac{1}{R}\frac{\partial P}{\partial \theta} = \frac{\rho v^2 \cdot ctg\theta}{R} \; ; \tag{1}$$

$$w\frac{\partial w}{\partial R} + \frac{u}{R}\frac{\partial w}{\partial \theta} + \frac{\Gamma^2}{2\pi R^3 \cdot \sin^2\theta} - \frac{v^2}{R} = \frac{\upsilon}{R^2}\frac{\partial^2 w}{\partial \theta^2} + g \cdot \cos\theta \; ; \tag{2}$$

$$w\frac{\partial v}{\partial r} + \frac{u}{R}\frac{\partial v}{\partial \theta} + \frac{vw}{R} = \frac{\upsilon}{R^2}\frac{\partial^2 v}{\partial \theta^2} + g \cdot \sin\theta \; ; \tag{3}$$

$$\frac{\partial w}{\partial R} + \frac{2w}{R} + \frac{1}{R}\frac{\partial u}{\partial \theta} = 0 \; , \tag{4}$$

with boundary conditions,

$$\theta = \frac{\alpha}{2} : u = v = w = 0 \; ; \tag{5}$$

$$\theta = \frac{\alpha}{2} - \frac{\delta}{R} : w = 0; \quad v = \frac{\Gamma}{2\pi R \cdot \sin\frac{\alpha}{2}}; \quad \frac{\partial u}{\partial \theta} = \frac{\partial v}{\partial \theta} = \frac{\partial w}{\partial \theta} = 0 \cdot \tag{6}$$

The gravitational force ρ·**g** is potential. It can be inserted into equations (2) and (3) in the pressure gradient *P.*

The solutions of the system of equations (1)-(4) with boundary conditions (5) and (6) were obtained by Pohlhausen method, which gives results in convergence with experimental measurements (Taylor, 1950), (Cooke, 1952), (Bloor & Ingham, 1977), (Som, 1983). Pohlhausen's method, consists in assuming an arbitrary forms of distribution of velocities in the boundary layer, which to satisfy the conditions to the body surface and to the border of boundary layer and also to meet the integrals of impulses.

Thus, we assume that distributions the velocity components in the boundary layer are describing with the relations:

$$v = \frac{F}{2\pi R \cdot \sin\left(\frac{\alpha}{2}\right)} \cdot \left(2\eta - \eta^2\right) = f_v(R) \cdot F_v(\eta); \tag{7}$$

$$w = \frac{\Gamma \cdot E(R)}{2\pi R \cdot \sin\left(\frac{\alpha}{2}\right)} \cdot \left(\eta - 2\eta^2 + \eta^3\right) = f_w(R) \cdot F_w(\eta); \tag{8}$$

$$u = \frac{\delta(R) \cdot \Gamma}{2\pi R \cdot \sin\left(\frac{\alpha}{2}\right)} \cdot \left[\frac{dE(R)}{dR} + \frac{E(R)}{R}\right] \cdot \left(\frac{1}{2}\eta^2 - \frac{2}{3}\eta^3 + \frac{1}{4}\eta^4\right) = f_u(R) \cdot F_u(\eta), \tag{9}$$

where $\eta = R \cdot [(\alpha/2) - \theta]/\delta(R)$.

Boundary layer thickness $\delta(R)$ and dimensionless parameter $E(R)$ were determined by numerical solution of the system of equations, obtained by calculating impulse integrals for this case (Taylor, 1950). Numerical solutions obtained were approximated with relations:

$$\delta(R)=\frac{R_0}{\sqrt{\dfrac{\Gamma}{2\pi\upsilon\cdot\sin\left(\dfrac{\alpha}{2}\right)}}}\left[4{,}38\cdot\left(1-\frac{R}{R_0}\right)^{1{,}75}-9{,}36\cdot\left(1-\frac{R}{R_0}\right)^{1{,}37}+5{,}8\cdot\left(1-\frac{R}{R_0}\right)^{0{,}57}+1\right] \quad (10$$

$$E(R)=7{,}569-4\cdot\frac{R}{R_0}-2{,}5\cdot\left(\frac{R}{R_0}\right)^{0{,}5}-0{,}848\cdot\left(\frac{R}{R_0}\right)^{15} \quad (11)$$

The results are presented graphically in Figures 2-6.

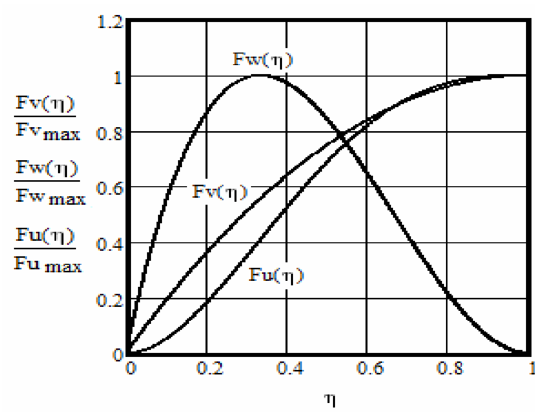

Fig. 2. The profiles of velocity components in the boundary layer

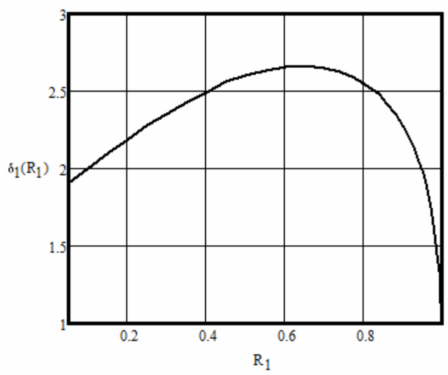

Fig. 3. The profile of boundary layer in dimensionless coordinates

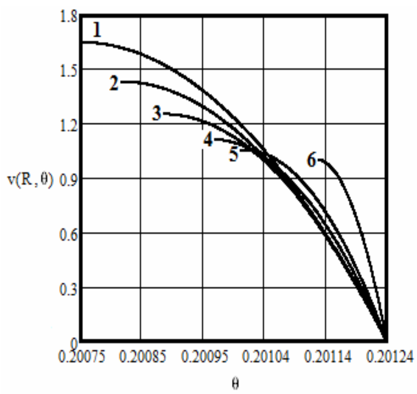

Fig. 4. Circular velocity distribution in the boundary layer on the direction normal to the conical wall:

R/R_0: 1- 0.608; 2-0.7; 3-0.8; 4-0.9; 5-0.95; 6-1.0

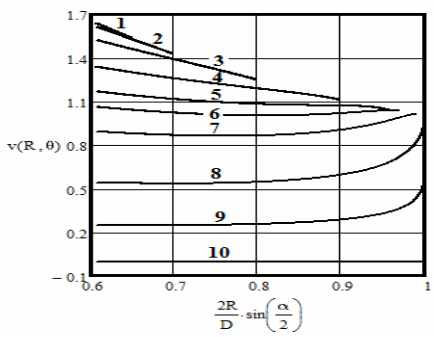

Fig. 5. Circular velocity distribution in the boundary layer on the wall conical longitudinal direction:

θ, [rad]: 1-0.20078; 2-0.20082; 3-0.20088; 4-0.20096; 5-0.20101; 6-0.20104; 7-0.20108; 8-0.20115;
9-0.20120; 10-0.2012

According with relations (7)-(9) the profiles of radial velocity *u*, circular velocity *v* and axial velocity *w*, are described with the functions $F_u(\eta)$, $F_v(\eta)$ and $F_w(\eta)$ (Figure 2). To be presented in the same diagram, functions $F_u(\eta)$, $F_v(\eta)$ şi $F_w(\eta)$ have been divided to their maximum values that relate between them $F_{v\ \max} : F_{w\ \max} : F_{u\ \max}$ = 1 : 0.148 : 0.083.

$\delta_1(R_1) = [\delta(R)/R_0] \cdot \sqrt{\Gamma/2\pi\nu \cdot \sin(\alpha/2)}$, where $R_1 = R/R_0$ have the profile shown in Figure 3. Equations (10) and (11) are valid in all the range of the variable R_1 (from 0.05 to 1). During this interval the distribution $\delta_1(R_1)$ reaches a maximum value for $R_1 = 0{,}6...0{,}67$, then decreases tending to the value $\delta_1(1)$ given by the boundary conditions imposed by the solution of boundary layer equations for cylindrical chamber (wicket gate) situated above conical channel (Figure 1). Thus, depending of the value of the generatrix length R^* of the conical channel, the thickness of boundary layer will be maximum on edge of the output orifice from conical channel with diameter *d* if $R^*/R_0 \geq 0{,}6$. For $R^*/R_0 < 0{,}6$ the thickness of boundary layer will be maximum in a section of conical channel.

As approaching by surface of the conical wall (with increasing the angle θ), circular velocity *v* decreases up to zero from maximum values at the outer border of the boundary layer which are reduce by increasing the polar radius *R* (Figures 4 and 5). In outside of the boundary layer, the circular velocity in area of potential flowing is inversely proportional to the radius *r* of rotation of the fluid (v~1/*r*) and *r* increases with *R* according to the relation $r = R \cdot \sin(\alpha/2)$, which explains this result.

Axial velocity distribution *w* attests a maximum within the boundary layer, whose value is reduced by increasing the polar radius R (Figure 6), observing and a movement towards the surface of conical wall. Velocity *w* is reduced with increasing *R* (Figure 7) from zero to the maximum value, which increases with angle θ (ie the extent approaching conical wall surface).

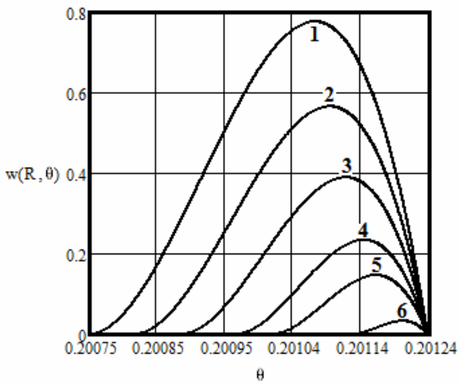

Fig. 6. Axial velocity distribution in the boundary layer on the normal direction to the conical wall:

R/R_0: 1- 0.608; 2-0.7; 3-0.8; 4-0.9; 5-0.95; 6-1.0

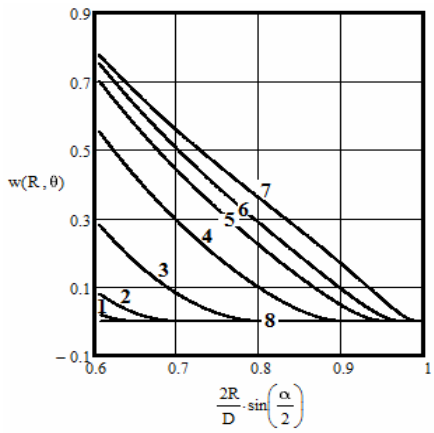

Fig. 7. Axial velocity distribution in the boundary layer on the wall conical longitudinal direction:

θ, [rad]: 1-0.20078; 2-0.20082; 3-0.20088; 4-0.20096; 5-0.20101; 6-0.20104; 7-0.20108;

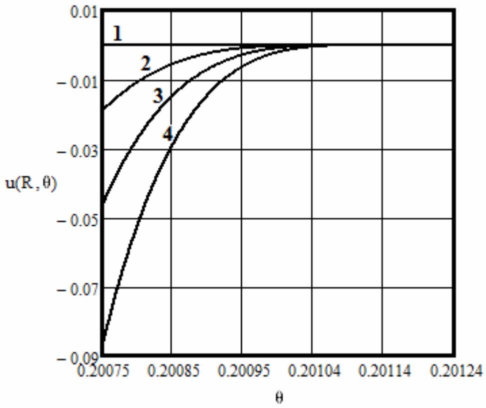

Fig. 8. Radial velocity distribution in the boundary layer on the normal direction to the conical wall:

R/R_0: 1-0.8; 2-0.990; 3-0.998; 4-1.0

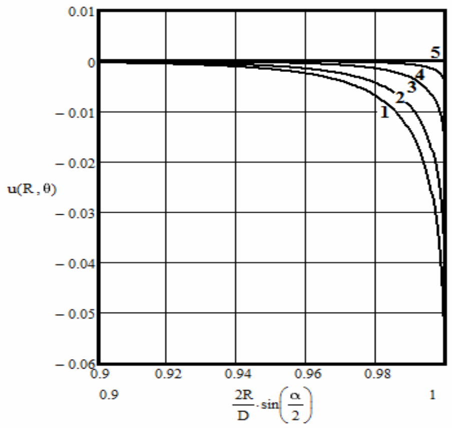

Fig. 9. Radial velocity distribution in the boundary layer on the wall conical longitudinal direction:

θ, [rad]: 1-0.20078; 2-0.20082; 3-0.20088;
4-0.20096;
5-0.20124

Radial velocity *u* decreases from the maximum value at the outer border of the boundary layer to zero as the angle θ increases (Figure 8), as well as reducing the polar radius *R* (Figure 9). Maximum value of velocity component *u* increases with increasing polar radius R. In the fluid layer that adheres directly to the surface of the conical wall, but and for $R/R_0 < 0{,}94$ velocity *u* is practically zero. Minus sign of the velosity *u* component shows that it is oriented in oppositiom with the direction of increasing of rotation radius *r* of the fluid, ie fluid flows from the boundary layer to the center of conica channel with velocity *u*.

In Figures 4-9, velocitiy components are presented as dimensionless, by dividing the values given by relations (7)-(9) to $\Gamma/2\pi R_0 \sin(\alpha/2)$.

2.2. Velocities distributions in zones of potential flowing and forced vortex

In zones of potential flowing and forced vortex (Figure 1), Navier-Stokes equations of motion can be replaced by Euler equations for ideal fluid, the kinematic coefficient of viscosity is null $(\nu = 0)$. Particular solution of these equations, obtained by Rankine (Wu et al., 2006), describes an axially symmetric vortex flowing, with circular velocity that increases from zero on vortex axis with increasing of radius according to the relationship $v = \omega \cdot r$, to a value $r = r_0$, that delimits the forced vortex zone by free vortex zone (potential flowing). Reaching maximum value for $r = r_0$, the circular velocity decreases in potential flowing area according to the law $v = \omega r_0^2 / r$. In these relations ω is the angular velocity of rotating of fluid in its entirety as a solid body in the forced vortex field.

In this case, have to be respect the balance between centrifugal force and pressure gradient P, leading to fluid pressure distribution on the radius. Pressure P_0, on vortex axis is less than the pressure P_∞, in the surrounding fluid at the big distance:

$$P_0 = P_\infty - \frac{\rho\omega^2 r_0^2}{2}\,, \tag{12}$$

where ρ is the density of fluid, $\left[kg/m^3\right]$. Under these conditions is established the ciclostrofic regime of rotation of incompressible fluid with pressure drop in the vortex center depending on the angular velocity ω.

The pressure P_∞, outside the forced vortex is determined with relationship:

$$P_\infty = P_a + \rho\frac{c^2}{2} + \rho g z\,, \tag{13}$$

where P_a is the atmospheric pressure, [Pa]; *c* - absolute velosity of the fluid in the potential flowing, [m/s].

Directly proportional relationship of circular velocity *v* and *r* $(v = \omega\cdot r)$ in the field $r < r_0$ and inverse proportional relationship of circular velocity *v* and *r* $\left(v = \omega\cdot r_0^2/r\right)$ in the field $r > r_0$, lead to the automatically annulment of member related of the viscosity in the Navier-Stokes equation right. It would seem that the Rankine's vortex can exist without be mitigating and in viscous fluid. But the turning point of the curve x, second degree derivative becomes infinite, fact which formal corresponds to an unreal of viscosity, infinitely large at this point.

Vortices that appear in real viscous liquids have a profile without singularity point, as in the stationary vortex of Burgers's (Wu et al., 2006).

Thus happens in the conservative systems, closed, in which the kinetic energy of vortex is dissipates and velocity profiles are abating over time.

Another situation occurs in open systems with drain and unlimited influx of substance from the environment. This case corresponds to water vortex formed in the conical channel of micro hydropower plant.

In this case is forms a drowned water jet with radius of drain hole by order *d*/2, through which water flows under the action of gravity with axial velocity *w*, increasing in the direction of flow. Instead of water drained from the outside volume, the jet is fed with new portions of water, due of radial velocity which is oriented to middle of jet, with values. Velocities *w* and *u* are interlinked with incompressible fluid continuity equation, which in cylindrical coordinates for axial-symmetric flowing is written as:

$$\frac{\partial u}{\partial r} + \frac{u}{r} + \frac{\partial w}{\partial z} = 0\,. \tag{14}$$

Therefore, the general solutions of velosity fields in forced $\left(r \le r_0\right)$ and free $\left(r > r_0\right)$ vortices are:

$$v = \omega\cdot r;\quad u = -\frac{\gamma}{2}\cdot r;\quad w = \gamma\cdot z,\quad if\quad r \le r_0\,; \tag{15}$$

$$v = \omega\cdot\frac{r_0^2}{r};\quad u = -\frac{\gamma}{2}\cdot\frac{r_0^2}{r};\quad w = 0,\quad if\quad r > r_0\,; \tag{16}$$

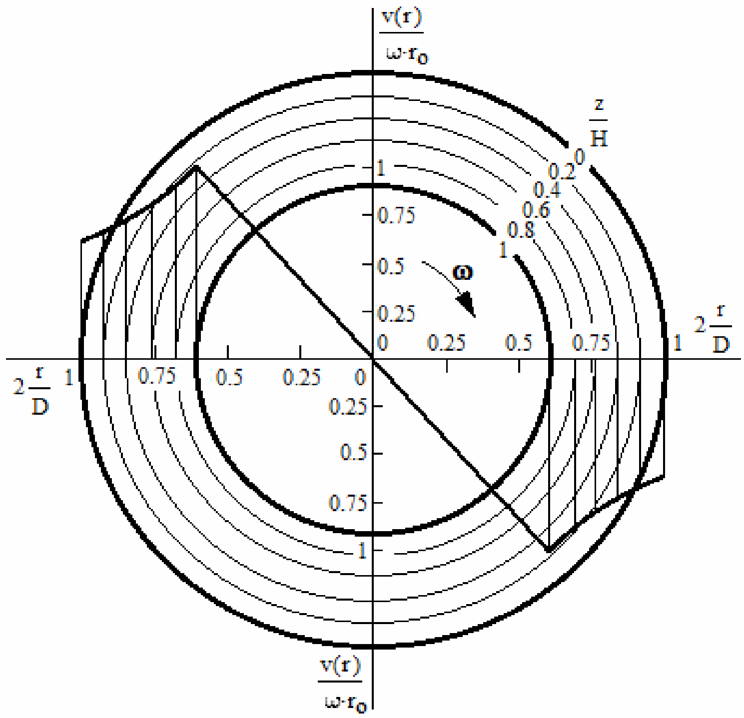

Fig.10. Circular velocity distribution in forced vortex and potential flow zones:

ω=9.653 s^{-1}; D=2.6 m; d=1.58 m

Continuity equation (14) in this case will be automatically respected. These considerations exactly correspond to results obtained above for the boundary layer. Values of r_0 and γ from relations (15) and (16) is determined equaling values of those velosities to outer border of boundary layer with values calculated with these formulas.

Circular velocity *v* (Figure 10) and radial velocity *u* (Figure 11) is continuous at outer surface of forced vortex $(r = r_0)$, even if it has a turning point on this surface, while the axial velocity *w* (Figure 12) for $z \neq 0$, varies in threshold. Such a threshold for *w*, in the turning point $r = r_0$, which depends linearly on *z*, is strictly speaking unstable. This instability is known as instability of tangential discontinuity of velosity (Landau & Liphshitz, 1988), which at the occurrence of fluctuations of velocity and pressure at the surface of fluids moving at different velosities, increasing exponentially in time. Thus, at the nonlinear stage development of the instability, a turbulent structure appears under the form a almost periodic series of vortices known as "cat's eyes" (Fridman, 2008). In this turbulent and quasi-stationary surface layer occurs mitigation gap of axial velocity and return point of circular and radial velocities.

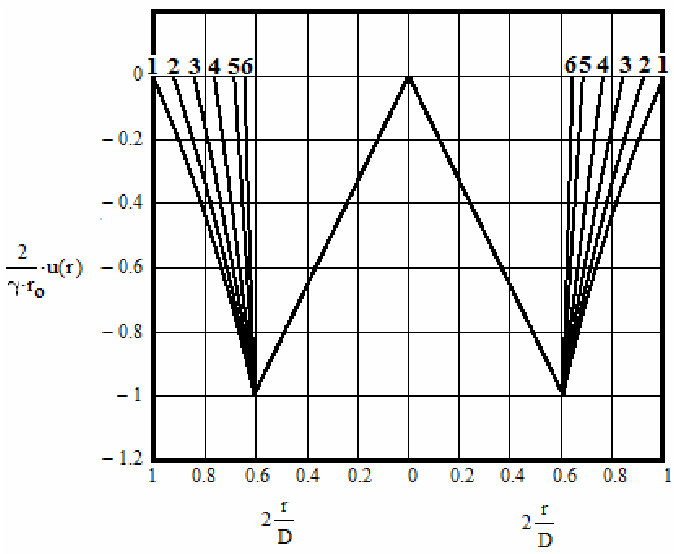

Fig. 11. Radial velocity distribution in forced vortex and potential flow zones:

H=2.5 m; z/H: 1-0; 2-0.2; 3-0.4; 4-0.6; 5-0.8; 6-0.9; γ=0.418 s^{-1}

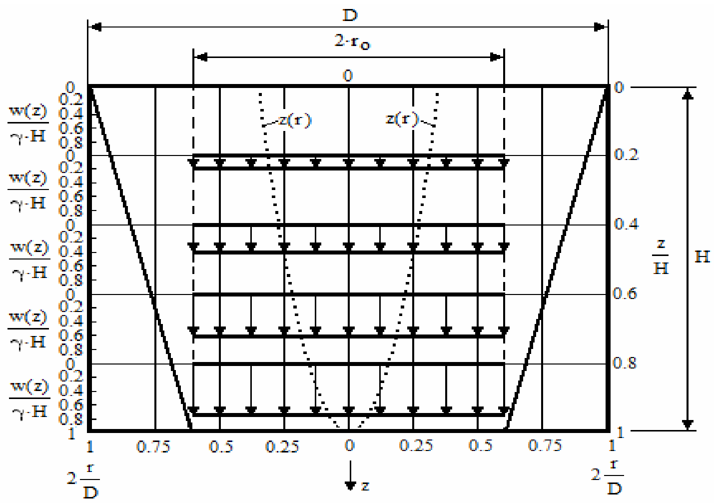

Fig. 12. Axial velocity distribution in forced vortex and potential flow zones

z(*r*) - free surface of water and air separation in cavern at fluid rotation (γ=0.418 s^{-1}; ω=9.653 s^{-1}; σ=0.07269 N/m; ρ=998.2 kg/m^3)

For the forced vortex zone, Euler equations in projections on the axes *r* and *z* are written in the form ($\partial p/\partial\theta = 0$):

$$\left(\frac{\gamma}{2}\right)^2 \cdot r - \omega^2 r = -\frac{1}{\rho}\cdot\frac{\partial}{\partial r}\left(p - \frac{\sigma}{r}\right); \tag{17}$$

$$\gamma^2 \cdot z = -\frac{1}{\rho}\cdot\frac{\partial p}{\partial r} - g\,, \tag{18}$$

which common integral is:

$$\frac{p}{\rho} = \frac{\omega^2 r^2}{2} - \frac{\gamma^2}{8}\cdot r^2 + \frac{\gamma^2}{2}\cdot z^2 - - g\cdot z - \frac{\sigma}{\rho\cdot r} + const\,. \tag{19}$$

At the free surface of the rotating moving fluid (interface between air and water cavern, Figure 1) pressure $p = const$. Therefore free surface of the fluid is surface of a paraboloid of rotation (Figure 12, curve z(r)), described by the equation:

$$z(r) = \frac{g - \sqrt{g^2 - 2\gamma^2\left(\frac{\omega^2 r^2}{2} - \frac{\gamma^2}{8}\cdot r^2 - \frac{\sigma}{\rho\cdot r}\right)}}{\gamma^2}\,. \tag{20}$$

Influence of capillary pressure of water σ/r, where σ is the coefficient of surface tension, is noticeable at radius of the cavern air $r < 1\cdot 10^{-2}\ m$. In reality this phenomenon is more complex, being substantial influenced by capillary waves, that propagate on the free surface of the fluid.

3. THE WATER FLOWING THROUGH THE CONICAL CHANNEL IN THE PRESENCE OF TURBINE STAGES

To simulate water flowing through the conical channel in the presence of the turbine stages was implemented the gravitational vortex turbine 3D CAD project in software SolidWorks at experimental model scale (Figure13). Simulation has been developed in Comsol software.

In Figure 14 is presented the velocity field and stream lines for sink strength Q = 0.5 l/s and for vortex strength Γ = 0.3 m^2/s. It notes the formation of swirls in every area between the blades. Water velocity increases rapidly as it approaches the drain hole and strongly depends on Q and Γ.

In the presence of the multistage turbine rotor, the flow structure changes qualitatively. Rotor blades require boundary conditions of water velocity equal to the speed of their surfaces, speed is not known 1a priori, but the settlement is determined depending on when torque resistance that opposes the rotation shaft and velosity diagrams into and out of blades, due to absolute speed water entry into blades, blade profile, entry and exit angles of the blades and blade fluid.

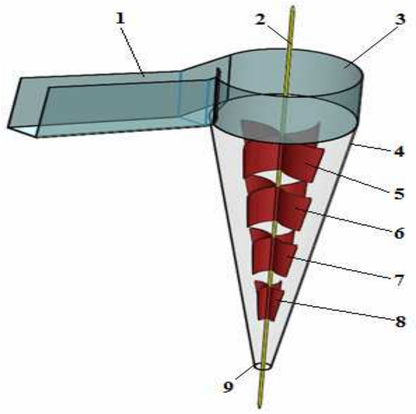

Fig. 13. The 3D CAD project of experimental micro hydropower converter:

1-supply channel: 2-shaft; 3- wicket gate; 4-conical channel; 5,6,7,8- turbine stages; 9- drain hole

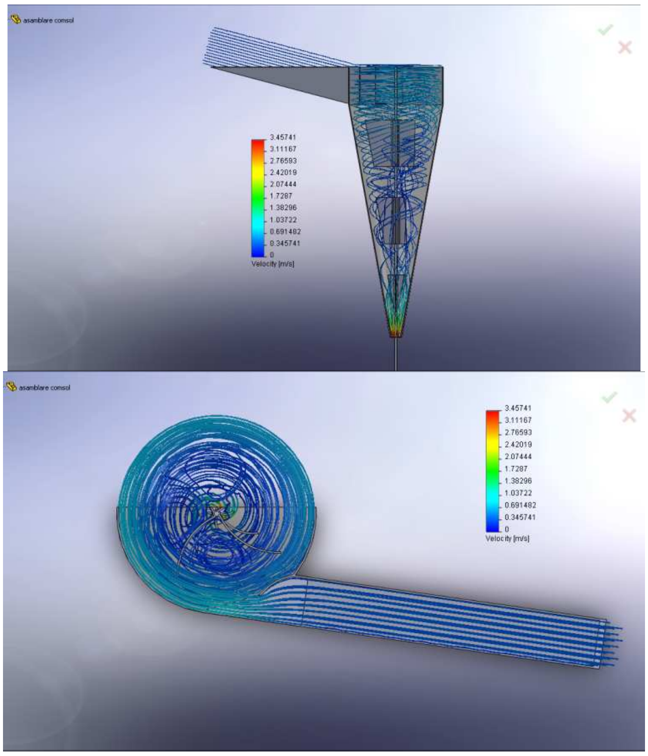

Fig.14. Structure of water flow through the conical channel in the presence of the turbine stages:

Q = 0.5 l/s; Γ = 0.3 m^2/s

4. CONCLUSIONS

Were determined the velosities fields in conical channel of the converter with gravitational vortex in the absence and in the presence of turbine stages. In the first case, for the boundary layer, the solutions of system of equations with these boundary conditions were obtained by the Pohlhausen method, and in the zones of potential flowing and of forced vortex, by customizing of general solutions of the Rankine vortex at the boundary conditions at outer border of the boundary layer. In the second case were realized computer simulations of flowing in Comsol software.

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ENTROPY GENERATION IN A STEADY STATE HEAT CONDUCTION: A STUDY FOR THE PLANE WALL

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In technical applications, there are many processes developed at high temperatures. Loss of heat to the surrounding represent a loss of energy, an important task of engineers being to minimize heat losses. In all types of heat transfer processes, thermodynamic irreversibility is associated with entropy generation, which results in the destruction of available work. In a pure heat conduction process, the generation of entropy is the result of heat transfer through a finite temperature difference. This paper investigates entropy generation during one-dimensional steady state conduction through a plane wall. Are considered two situations: uniform thermal conductivity without additional internal heat source and uniform thermal conductivity with additional internal heat source. For the both situation will be discussed the temperature distribution in the plane wall.

***Keywords**: entropy generation, conduction, heat, thermal conductivity*

1. INTRODUCTION

Conduction is the heat transfer mechanism produced by molecular action, with no motion of the medium. During conduction, heat flows from regions with high temperatures to regions with lower temperatures. It is met especially within solid, but also liquid and gaseous medium, or between different mediums that make direct physical contact with each other.

The irreversibility of real processes is the reason for degradation of all forms of energy. According to the Second Law of Thermodynamics, the measure of this degradation is the increase of entropy (or the entropy generation).

The above is expressed by Gouy-Stodola Theorem, which states that in any open system, the work lost by irreversibility, W_λ, and the entropy generation, S_{gen}, are related as:

$$W_\lambda = T_a S_{gen} \tag{1}$$

where T_a is the ambient temperature.

Heat transfer between two systems of different temperatures is an example of typical irreversible process. During heat conduction process, the entropy generation is due exclusively to heat transfer through a finite temperature difference, heat transfer through a finite temperature difference being equivalent to the destruction of its availability. Temperature distribution in the conducting medium depends on the thermophysical properties of the medium, internal energy generation and thermal conditions imposed at the boundaries of the medium.

Assuming steady-state conditions and no internal heat generation (q=0), the temperature distribution for one-dimensional conduction in a plane wall is a liniar function:

$$T(x) = c_1 x + c_2 \tag{2}$$

while assuming steady-state conditions and internal heat generation (q≠0), results:

$$T(x) = -\frac{\dot{q}}{2k}x^2 + c_1 x + c_2 \tag{3}$$

where k is thermal conductivity (W/mK) and above k=const.

Entropy generation minimization is a modeling tool used by engineers in design optimization.

This paper deals with entropy generation minimization during one-dimensional conduction in a plane wall in two cases exposed in the following.

2. MATHEMATICAL MODEL

2.1. Situation 1: *Constant thermal conductivity (k=const), no internal heat generation (q=0)*.

The schematic diagram of one-dimensional heat conduction in an infinite plane wall is given in Figure 1. The heat flows spontaneously from the source with a higher temperature to a source with a lower temperature (thus $T_1 > T_2$).

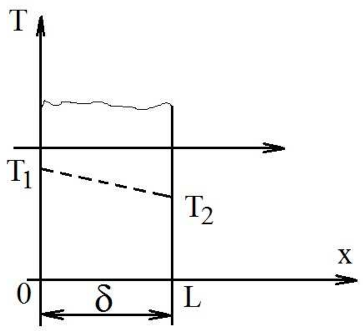

Fig. 1. Boundary value problem of first kind

This situation is governed by the following differential equation:

$$\frac{d}{dx}\left(k\frac{dT}{dx}\right) = 0 \tag{4}$$

In the cartesian system, the conduction equation reduces to the ordinary differential equation:

$$\frac{d^2T}{dx^2} = 0 \tag{5}$$

The local entropy generation is:

$$s''' = \frac{k}{T^2}\left(\frac{dT}{dx}\right)^2 \tag{6}$$

The entropy generation is obtained by integrating Eq. (6):

$$s_{gen} = \int_0^L s''' dx = \int_0^L \frac{k}{T^2}\left(\frac{dT}{dx}\right)^2 dx \tag{7}$$

The optimum temperature variation that minimizes the entropy generation satisfies the Euler equation:

$$\frac{\partial F}{\partial T} - \frac{d}{dx}\left(\frac{\partial F}{\partial T_x}\right) = 0 \tag{8}$$

In Eq. (8):

$$F = \frac{k}{T^2}\left(\frac{dT}{dx}\right)^2$$

$$T_x = \frac{dT}{dx}$$

The final form of the temperature distribution is:

$$\frac{d^2T}{dx^2} - \frac{1}{T}\left(\frac{dT^2}{dx}\right) = 0 \tag{9}$$

Which is different from the classical Laplace heat conduction equation (see Eq. (5)).

In order to satisfy the heat conduction equation, the first term from Eq. (9) should be null. So, the solution for the optimum temperature variation is found from the second term from Eq. (9), the optimum temperature variation that satisfies the heat conduction equation and also the heat Euler equation being:

$$T = const. \tag{10}$$

But this situation can take place only when T_1=T_2, heat transfer and entropy generation being zero for such a temperature distribution.

For boundary conditions of the first kind:

0; T(0)=T_1
x=L; T(L)=T_2

solution to Eq. (9) is:

$$T(x) = T_1\left(\frac{T_2}{T_1}\right)^x \tag{11}$$

According to Eq. (2), the total entropy generation results:

$$S_{gen} = kAC_1^2\int_0^x \frac{dx}{(C_1x+C_2)^2} \tag{12}$$

where A – wall area, m^2.

After solving the integral and inserting the boundaries, we get:

$$S_{gen} = \frac{kAC_1}{C_2}\left(1-\frac{C_2}{C_1x+C_2}\right) \tag{13}$$

The two constants from above are found as:

$$C_1 = \frac{T_2-T_1}{\delta} \tag{14}$$

$$C_2 = T_1 \tag{15}$$

Writing $\theta = \frac{T_1}{T_2}$ (16)

Results the non-dimensional entropy generation as:

$$\frac{S_{gen}}{\frac{kA}{\delta}} = \frac{(\theta-1)^2}{\theta}\cdot\frac{\frac{x}{\delta}}{\theta-(\theta-1)\frac{x}{\delta}} \tag{17}$$

2.2. Situation 2: *Constant thermal conductivity (k=const), with internal heat conduction (q≠0).*

In this situation, the one-dimensional steady state heat conduction equation is:

$$\frac{d^2T}{dx^2}+\frac{q(x)}{k}=0 \tag{18}$$

Taking a look to Eq. (9), the internal heat generation results to be:

$$q(x)=-\frac{k}{T}\left(\frac{dT}{dx}\right)^2<0 \tag{19}$$

The entropy increase of the whole process is positive and given by:

$$s_{gen}=-\int_0^L\frac{q(x)}{T(x)}dx=k\left(ln\frac{T_2}{T_1}\right)^2>0 \tag{20}$$

3. RESULTS AND DISCUSSION

Table 1 shows the temperature distribution, given by dimensionless $T(x)/T_1$, in the plane wall, for a known heat conduction coefficient (k=1,0 W/mK), without and with additional heat source.

Table 1: Variation of $T(x)/T_1$ in a plane wall, for k=1,0 W/mK

no internal heat source and $q_{in}=q_{out}$=0,92 W/m²										
x	0,05	0,15	0,25	0,35	0,45	0,55	0,65	0,75	0,85	0,95
$T(x)/T_1$	0,95	0,87	0,78	0,70	0,56	0,49	0,40	0,32	0,26	0,16
with internal heat source (q=2,1 W/m²) and q_{in}=2,28 W/m² and q_{out}=0,18 W/m²										
x	0,05	0,15	0,25	0,35	0,45	0,55	0,65	0,75	0,85	0,95
$T(x)/T_1$	0,87	0,75	0,60	0,46	0,36	0,28	0,23	0,19	0,14	0,12

Table 2 shows the variation of the non-dimensional entropy generation depending on the non-dimensional variable x/δ, for different values of non-dimensional temperature θ, defined by Eq. (15).

Table 2: Non-dimensional entropy generation depending on x/δ and θ

θ=1							
x/δ	0	0,1	0,3	0,5	0,7	0,9	1,0
$S_{gen}/(kA/\delta)$	0,0	0,0	0,0	0,0	0,0	0,0	0,0

θ=3							
x/δ	0	0,1	0,3	0,5	0,7	0,9	1,0
S_{gen}/(kA/δ)	0,0	0,15	0,18	0,28	0,55	0,93	1,29
θ=5							
x/δ	0	0,1	0,3	0,5	0,7	0,9	1,0
S_{gen}/(kA/δ)	0,0	0,15	0,22	0,42	1,16	2,17	3,20

Values of dimensionless temperature $T(x)/T_1$ decrease with the increase of the thickness of the plane wall, for an additional internal heat source or not.

In the presence of an internal heat source, temperature distribution indicates lower values than without internal heat source.

Dimensionless entropy generation depends on two dimensionless variables: θ and x/δ.

Dimensionless entropy generation has a minimum (null) value when x/δ=0 and reaches its highest value for x/δ=1; this situation is available for any value of θ.

Dimensionless entropy generation presents higher values together with the increase of the two variables, x/δ and θ.

4. CONCLUSIONS

In this paper, an analysis of entropy generation during one-dimensional steady state heat conduction in a plane wall has been carried out. Where discussed two cases: uniform thermal conductivity and no internal heat generation and uniform thermal conductivity and additional internal heat source.

Minimization of entropy generation in heat conduction is possible by introducing additional internal heat source.

Non-dimensional entropy generation depends on two non-dimensional variables: x/δ and T_1/T_2, the non-dimensional entropy generation increases with the increase of these two variables.

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EFFECT OF WELDING PROCESS ON MECHANICAL AND MICROSTRUCTURE PROPERTIES OF 5083 ALUMINIUM ALLOY JOINTS USED IN SHIPBUILDING

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The present investigation is aimed to study the effect of welding processes such as TIG and MIG on mechanical and microstructure properties of 5083 aluminium alloy. The preferred welding processes of this alloy are frequently tungsten inert gas (TIG) and metal inert gas (MIG) due to their comparatively easier applicability and better economy. In this alloy, the weld fusion zones typically exhibit coarse columnar grains because of the prevailing thermal conditions during weld metal solidification. This often causes inferior weld mechanical properties and poor resistance to hot cracking. Two sets of 5083 aluminium alloy plates which normally used in ship construction have been selected as a sample material. The mechanical testing and microsture examination were performed and the results are compared. From this study it is found that TIG joints of 5083 aluminium alloy showed superior mechanical properties compared to TIG joints.

***Keywords**:* 5083 Aluminium alloy, Mechanical properties, Welding process

1. INTRODUCTION

Aluminium alloys are widely used in marine, aerospace, automobile industries, railway vehicles, bridges, offshore structure topsides and high-speed ships due to its lightweight, corrosion resistance and higher strength to weight ratio. In all cases, welding is the primary joining method which has always, represents great challenge for designers and technologies. As a matter of fact, lots of difficulties are associated with this kind of joint process, mainly related to the presence of a tenacious oxide layer, high thermal conductivity, high coefficient of thermal expansion, solidification shrinkage and above all high solubility of hydrogen and other gases in the molten state. Aluminium alloys are readily available in various product forms. 5083 aluminium alloy (Al-Mg-Si alloys) is the most widely used medium strength aluminium alloy and has gathered wide acceptance in the fabrication of ship hull structures such as fast ferries, naval craft and workboats [2]. The preferred welding processes for aluminium alloys are frequently metal inert gas (MIG) welding and tungsten inert gas (TIG) welding due to their comparatively easier applicability and better economy but TIG welding more complex than MIG welding [5].

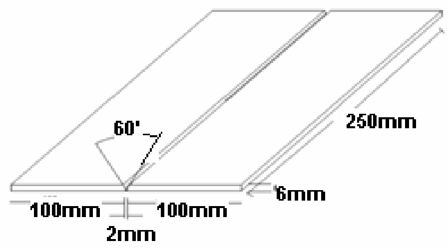
In the modern or global ship building construction, the best selection of the welding process is very important and given many advantages for the construction of the truly strong hull. In order to establish a proper welding procedure, it is necessary to know the material properties of the aluminium alloy being welded [5]. Different welding process produces different quality of welding joint. The variation welding parameters such as arc voltage and welding current can affect the welding strength and mechanical properties of 5083 aluminium

alloy joint [6]. Higher-strength aluminium alloy are more susceptible to hot cracking in the fusion zone and the Partially Melted Zone (PMZ) and losses of strength or ductility in the Heat Affected Zone (HAZ) [10]. Cracking occurs because of high stresses generated across the weld due to the high thermal expansion and subsequent contraction upon solidification [9]. The high thermal conductivity means that there is a high rate of cooling and so there is difficulty in heating up the parent metal round the weld zone to the adequate temperature to give complete fusion with the weld pool. An increase or decrease in the current will increase or decrease the weld penetration respectively.

Previous studies by Lakshminarayanan et. al. [1] was focused on the variation effect of welding process on tensile properties of AA6061 aluminum alloy joints. At present there was a limited study and detailed comparison has been reported on the mechanical properties of TIG and MIG welding of 5083 aluminium alloy. Therefore, this paper will evaluate the effect of different welding process on mechanical and microstructure properties of 5083 aluminium alloy joint used in shipbuilding.

2. EXPERIMENTAL PROCEDURE

In this investigation, the rolled plates of 5083 aluminium alloy were prepared as a sample to the required dimensions (250mm x 100mm x 6mm), with the angle is 60°. The joint type was a single ‘V’ butt joint as shown in Figure 1.



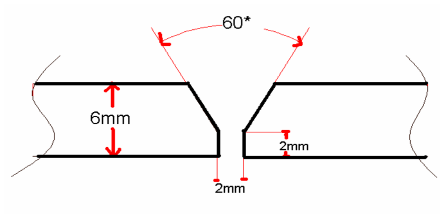


Fig. 1. Sample dimension and configuration

ER5356 and MTL 5183 grade filler rod and wire were used for TIG and MIG welding process, respectively. High purity (98%) argon gas was the shielding gas. Each welding process was carried out based on the standard Welding Procedure Specification (WPS). The welding conditions and process parameters presented in Table 1 were used to fabricate the joints. The sample is then cut into desired specimens size where each set had been cutted into 8 specimens as shown in Figure 2. American Society for Testing of Material (ASTM E8M - Standard Test Methods for Tension Testing of Metallic Materials) guidelines were followed to preparing the test specimens.

Table 1. Welding conditions and process parameters

Welding Parameter	TIG	MIG
Tungsten electrode dia. (mm)	3.2	-
Filler rod wire dia. (mm)	-	1.0
Voltage (volts)	20	20
Current (amps)	165	190

Welding speed (mm/min)	110	130
Heat input (kJ/mm)	1.080	1.403
Shielding gas	Argon	Argon
Gas flow rate (lit/min)	16	16
Polarity	AC	DCRP

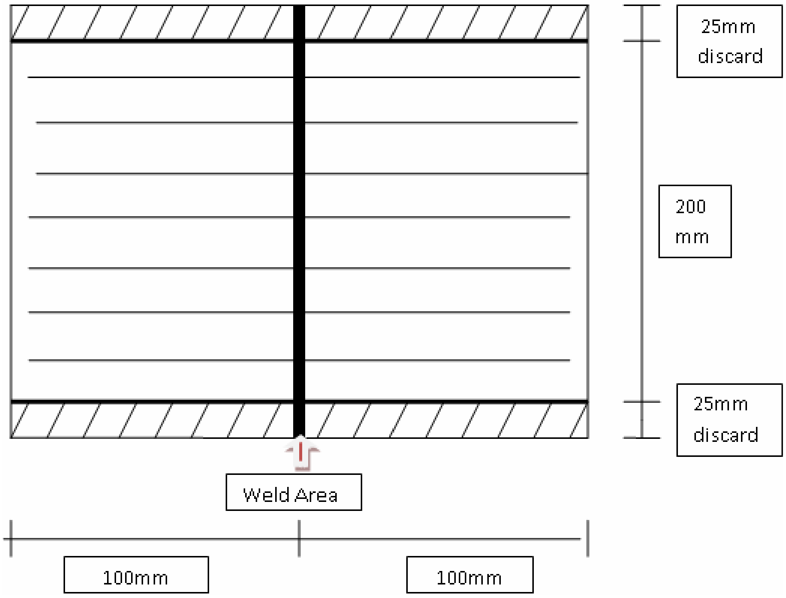


Fig. 2. Specimen size for each sample

3. EXPERIMENTAL RESULTS

The experiments were performed with constant welding current, arc voltage and welding speed for TIG and MIG welding process. The results are summarized according to the type of testing.

3.1 Tensile Test

The specimens were tested for tensile test using Instron tensile machine to determine the mechanical properties of 5083 aluminium alloy joints. The transverse tensile properties such as yield strength, tensile strength and percentage of elongation of 5083 aluminium alloy joints were evaluated. In each condition, two specimens for each process were tested and the average of the result have been summarized in Table 2.

Table 2. Result of Tensile Test

Process	Yield Strength (Mpa)	Tensile Strength (Mpa)	Maximum Strain mm/mm	Percent Elongation (%)
TIG	205.00	285.23	0.094	6.56
MIG	192.50	276.71	0.079	5.63

The average yield strength and tensile strength of TIG specimens are 205.00 MPa and 285.23 MPa respectively. On the other hand the average yield strength and tensile strength of MIG specimens are 192.50 MPa and 276.71 MPa respectively. This indicated the TIG specimens have higher strength values compared to MIG specimens. The TIG specimens also have a high value of elongation and reduction in the cross-sectional area which is 6.56% compared the MIG specimens 5.63%.

3.2 Hardness Test

Hardness test was performed to determine the ability of 5083 aluminium alloy to resist from being plastic deformation. Hardness values for 22 points across the weld cross section was measured using a Rockwell hardness testing machine and the average values are presented in Figure 3. The average hardness value of base metal and heat affected zone (HAZ) of MIG specimen are 34.88 and 27.05, respectively. While average value for TIG specimen are 21.35 and 20.93 at base metal and HAZ area respectively. However, the TIG specimen has a higher hardness value in the weld metal area which is 15.2 whereas MIG specimen is only 13.43. In overall MIG specimen shows more harden than TIG specimen after welding. This may be due to more heat input contributed by MIG process which is 1.403 KJ/mm compare to TIG process about 1.080 KJ/mm.

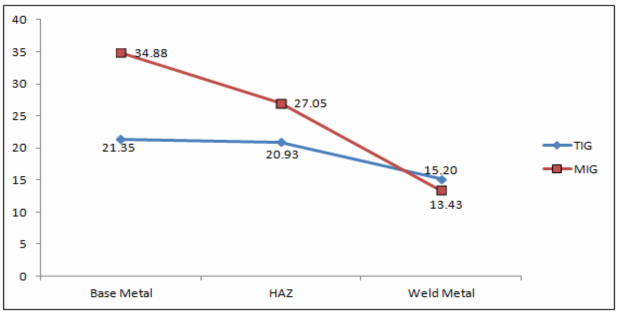


Fig. 3. Rockwell hardness value

3.3 Metallographic Examination

Microstructure of all joints was examined by using optical equipment Dino Lite taken at three locations which are base metal, weld metal and HAZ area. The results are displayed in Figure 4 and 5 for comparison purpose.

a) Base metal b) HAZ area c) Weld metal area

Fig. 4. Microstructure for TIG specimens (200x magnification)

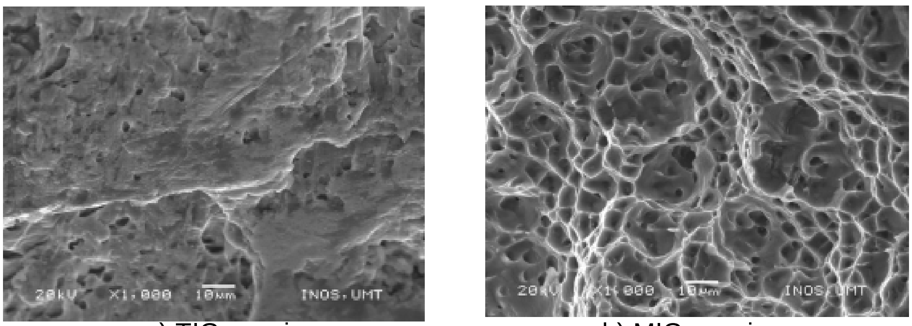
a) Base metal b) HAZ area c) Weld metal area

Fig. 5. Microstructure for MIG specimens (200x magnification)

The base metal of TIG and MIG sample contain coarse grains with uniformly distributed very fine precipitates. The Heat Affected Zone (HAZ) of TIG and MIG joints contain fine grains surface structure and this may be due to the fast heating of base metal and fast cooling of molten metal due to welding heat. The weld region of TIG process contains very fine surface and has higher bonding substance compared to MIG process which has low bonding substance. These fine particles are responsible for the good mechanical properties obtained by TIG process.

3.4 SEM examination

All the tensile specimens failed in the weld metal region. The fracture surface of tensile specimens of welded joints was analyzed using Scanning Electron Microscope (SEM) to reveal the fracture surface morphology. Figure 6 shows the fractographs of tensile specimens for TIG and MIG welding process. The displayed fractographs invariably consist of dimples, which indicate that most of the tensile specimens failed in a ductile manner under the action of tensile loading. An appreciable difference exists in the size of dimples with respect to the welding processes. Fine dimples are seen in TIG joint as shows in Figure 6(a). Since fine dimples are a characteristic feature of ductile fracture, the TIG joints have shown higher ductility (more elongation) compared to MIG joints as stated in Table 2. Course dimples has been observed in MIG joint in Figure 6(b). This may be due to the combined influence of a coarse grained weld metal region and a higher amount of precipitate formation at the grain boundaries. The dimples size exhibits a directly proportional relationship with strength and ductility. For example, if the dimples size is finer, then the strength and ductility of the respective joint is higher and vice versa.



a) TIG specimen b) MIG specimen

Fig.6. SEM fractographs of fracture tensile specimen

3.5 Bend test

The face and root bend test was performed to evaluate ductility and soundness of specimens. The results are presented in Figure 7. The bending stress value for TIG and MIG face bend are 4.04 MPa and 3.35 MPa respectively. On the other hand the bending stress value for TIG and MIG root bend are 3.07 MPa and 2.69 MPa respectively. In overall, TIG specimens have higher value of bending stress than MIG specimens. This indicates that TIG joints can absorb more stress compared to MIG joints.

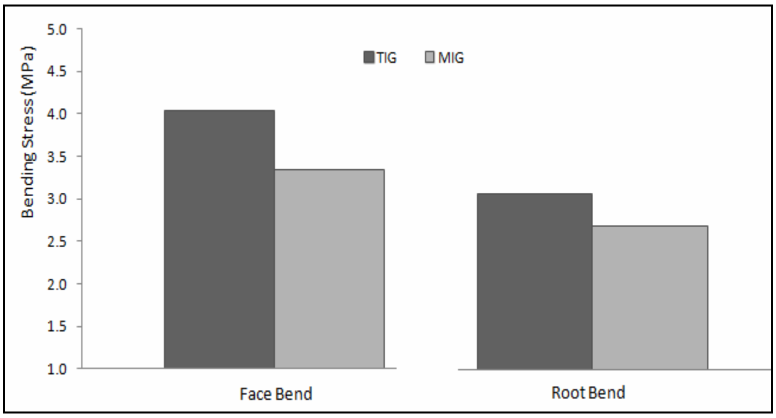


Fig.7. Face and root bending stress

4. DISCUSSION

The above results shows that the transverse tensile properties of of 5083 aluminium alloy joints are reduced by welding processes. Among two welded process, TIG joint shows superior tensile properties compared to MIG joints. Most of the tensile specimens failed in the weld region. This indicates that the weld region is comparatively weaker than other regions and hence the joint properties are controlled by weld region chemical composition and microstructure. It is also evident from the hardness test that weld region shows lower hardness than other regions. Mechanical test results shows the 5083 aluminium alloy joints that serves as TIG welded specimens have higher ultimate tensile strength of 285.23 MPa and face bending strength of 4.04 MPa. The weld metal hardness value of 15.20 Rockwell competes favourably with the hardness values from the MIG welded specimens. This was proved by the fine microstructure in HAZ and weld metal area for TIG specimens. MIG specimens have the lower performance close to the TIG specimens with ultimate tensile strength of 276.71 MPa, weld metal hardness value of 13.43 Rockwell and face bending strength of 3.35 MPa. Elongation value for TIG specimens is 6.56% while MIG specimens is 5.63%. This indicated that TIG specimens more ductile than MIG specimens.

Welding current and heat input was the most influential variable in a welding process. It controls the electrode melting rate and hence the deposition rate. The depth of penetration and the amount of base metal melted. If the current is too high at a given welding speed, the depth of fusion or penetration will be too great. Increase in welding current from MIG and TIG welding process refines the microstructures of weld deposit to a great area. Welding on the alloy area effect the residual stress and distortion due to the weld metal shrinkage. The grain size of the weld region also plays a major role in deciding the joint properties. The grain size of the weld region is influenced by the heat of the welding process. Based on two welding process used in this investigation to fabricate the joints, the MIG process has higher heat input compared to TIG process. Since MIG is a consumable electrode process, the filler metal is always connected to positive polarity of the direct current (DCRP). This leads to a large amount of heat generation at the filler metal end. Further, a current of 190A is pass in through a small diameter of filler metal (1.0mm) and the current density is very high in the MIG process. Very high arc temperature increases the peak temperature of the molten weld pool causing a slow cooling rate. This may be one of the reasons for lower hardness and inferior tensile properties of MIG joints.

In TIG process, the alternating current (AC) polarity is used and the high heat generation end is continuously changing. similarly whenever workpieces becomes positive, more heat is generated at this end. In one half of a cycle, electrode attains maximum heat and in the other half of a cycle, workpieces attains maximum heat and this will change in the next cycle [8]. Therefore, while using alternating current, the maximum heat generation end is not fixed as in the case of MIG process. Due to this reason, heat input of TIG is lower than for MIG process. Lower heat input and lower current density reduces the arc temperature and arc force in TIG welding process. Lower arc temperature reduces the peak temperature of the molten weld pool causing fast cooling. This may be one of the reasons for higher hardness and superior tensile properties of TIG joints compared with MIG joints.

The fracture surfaces of the tensile tested specimens were characterized using SEM to understand the failure patterns. SEM photographs were taken in weld region of the TIG and MIG joints. Based on the scanning electron microscopy (SEM) examination, the significant clear grain can be noticed in MIG specimen in comparison to the TIG specimen. The formation of the clear grain in MIG specimen during welding can be attributed to dendrite formation. The nonuniform distribution of the dispersoid in TIG specimen may be responsible to be nonuniform distribution of silicon after solidification. The spacing between the revolutionary pitches is indicative of the ductility of the welded joints. It shows that the more quantity of the dimple, the higher ductility (elongation) of the joint [3]. All the fracture surfaces invariably consist of dimples. This is an indication that most of the failure is the result of ductile fracture [7]. In these tensile testing, voids generally form prior to necking. However, if a neck is formed relatively earlier, the void formation becomes coarse [4]. Elongated dimples are seen in MIG specimen. The dimples on the fracture surface MIG specimen are larger than TIG specimen. This may be the evident for the higher ductility of the TIG specimens.

At shipyards, 5083 aluminium alloy is widely used as a material for construction of ship hull and structures. Based on this study, TIG welding process gave the better result compared to MIG welding process for all tested specimens. However, in real application of ship construction, MIG welding is the most popular process because its higher welding speed, greater deposition rates, easy to operate and more cheaper compared to TIG process.

5. CONCLUSIONS

In this paper, the mechanical and microstructure properties of TIG and MIG joints of 5083 aluminium alloy were evaluated. From this investigation, the following conclusions have been derived:

a) Based on two welded joints, the joints fabricated by TIG process exhibited higher strength value of ultimate tensile strength (UTS) compared to MIG joints.
b) Hardness value is higher in base metal, followed by heat affected zone (HAZ) and low in weld metal area irrespective of welding process. In average hardness value of MIG joints is higher than TIG joints.
c) TIG welded joints are more ductile than MIG joints.

d) Metallographic images revealed that MIG joints have coarser surface area while TIG joints have finer surface area.
e) The fracture surface morphology analyzed by Scanning Electron Microscope (SEM) revealed that TIG joints have higher bonding substance and finer surface compared to MIG joints.

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THEORETICAL STUDY FOR EFFICIENT LENGTH AND DIAMETER APPLIED TO A COMPRESSED AIR INSTALLATION

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A compressed air installation becomes efficie4nt if the investment made leads to minimal expenses per cubic meter of compressed air. This is why we will analyze it from the economic viewpoint. All parts of the installation have a significant contribution in investment and expenses.

Keywords: expenses, economic diameter, efficient length, compressorpp

1. COMPUTATION OF EFFICIENT DIAMETER

In the case when the piping network of the installation represents an important percentage of the total value it becomes necessary to determine the economic diameter of the pipes. The computation of the investment "I" for a piece of the pipe is done by a formula of the kind:

$$\mathrm{I} = f_{\mathrm{I}}(D) = \left(a + bD + cD^2\right)L \tag{1}$$

Where:
D – section diameter [m]
L – length o fthe piece of pipe [m]p
a, *b*, *c* – coefficients determined by the values (*D, I/L*), and the price for each piece of the pipe.
Annual expenses consist of:
a) The electric energy cost *E* used by the compressors;
b) Expenses *N* with:
- q_0 – production;
- q_s – salaries;
- q_m – assembly and maintenance.

The energy cost *E* is given by:

$$E = \frac{c \cdot \tau}{\eta_c \cdot \eta_m \cdot 1000}\left(\frac{p_2}{\rho_2} + \frac{W_2^2}{2} + \frac{\Delta p_{12}}{\rho_m} - \int_{V_1^2}^{V} \rho dv\right)\left(M_2 + \Delta M_{12}\right) \tag{2}$$

where:
c – electric energy price [ROL/kWh]

τ – number of hours of functioning per year [h]
η_c – compressor efficiency;
ρ_2 – compressed air density at the outlet of the piece of pipe considered [kg/m^3];
W_2 – flow velocity at the outlet of the piece of pipe considered [m/s];
Δp_{12} – drop in pressure alond the piece of pipe considered [N/m^2];
ρ_m – average density along the piece of pipe considered [kg/m^3];
M_2 – mass flux at the outlet [kg/s];
ΔM_{12} – drop in mass flux along the pipe [kg/s].

Substituting the therms in equation (2) by their expression:

$$W_2 = \frac{4M_2}{\rho_2 \cdot \pi \cdot D^2}\left[m/s\right] \tag{3}$$

$$\frac{\Delta p_{12}}{\rho_m} = \frac{8\lambda L\left(M_2 + \Delta M_{12}\right)^2 R^2 T_m^2}{\pi^2 D^5 p_m^2}\left[Nm/kg\right] \tag{4}$$

$$\Delta M_{12} = aDL\left(\frac{p_m}{10^5}\right)^{1,3}\left[kg/s\right] \tag{5}$$

thus the cost of electric energy will be:

$$\begin{aligned} E = {} & \frac{c\tau}{\eta_c \eta_m 1000}\left\{\left[\frac{p_2}{\rho_2} - \frac{R}{n-1}\left(T_1 - T_2\right)\right]M_2 + \left[\frac{p_2}{\rho_2} - \frac{R}{n-1}\left(T_1 - T_2\right)\right]\right. \\ & aDL\left(\frac{p_m}{10^5}\right)^{1,3} + \frac{8\lambda L R^2 T_m^2 M_2^3}{\pi^2 p_m^2}\frac{1}{D^5} + \frac{1}{D^4}\left[\frac{8M_2^3}{\pi^2 \rho_2^2} + \frac{24\lambda L^2 R^2 T_m^2 M_2^2 a}{\pi^2 p_m^2}\left(\frac{p_m}{10^5}\right)^{1,3}\right] \\ & \frac{1}{D^3}\left[\frac{8M_2^2 aL}{\pi^2 \rho_2^2}\left(\frac{p_m}{10^5}\right)^{1,3} + \frac{24\lambda L^3 R^2 T_m^2 M_2^2 a^2}{\pi^2 p_m^2}\left(\frac{p_m}{10^5}\right)^{2,6}\right] + \\ & \left. + \frac{8\lambda L^4 R^2 T_m^2 a^3}{\pi^2 p_m^2}\left(\frac{p_m}{10^5}\right)^{3,9}\frac{1}{D^2}\right\} \end{aligned} \tag{6}$$

Equation (6) can also be written as:

$$E = H\left(A + BD + \frac{C}{D^5} + \frac{F}{D^4} + \frac{G}{D^3} + \frac{K}{D^2}\right) \tag{7}$$

Annual expenses N can be computed as a fraction of total investment:

$$N = \left(q_0 + q_3 + q_m\right)\left(a + bD + cD^2\right)L$$

During the T years of recuperation of expenses the sum of all expenses is given by:

$$S = \left(a + bD + cD^2\right)L + \sum_{i=1}^{T}\left\{\left[H\left(A + BD + \frac{C}{D^3} + \frac{F}{D^4} + \frac{G}{D^3} + \frac{K}{D^2}\right) + \right.\right.$$
$$\left.\left. + \left(q_0 + q_s + q_m\right)\left(a + bD + cD^2\right)L \quad \right]\left(\frac{1}{1+q_r}\right)^i\right\} \tag{8}$$

where
q_r- updating rate of annual expenses.

The economic solution for the diameter D is obtained as a critical point of the expression in (8):

$$\frac{\partial S}{\partial D} = L(b + 2cD)\left[1 + \left(q_0 + q_s + q_m\right)\sum_{i=1}^{T}\left(\frac{1}{1+q_r}\right)^i\right] +$$
$$+ H\left(B + 5\frac{C}{D^6} - 4\frac{F}{D^5} - 3\frac{G}{D^4} - 2\frac{K}{D^3}\right)\sum_{i=1}^{T}\left(\frac{1}{1+q_r}\right)^i = 0 \tag{9}$$

The solution of equation (9) can easily be computed using Newton's method and its implementation is not so complicated due to the fact that the expression under consideration is a rational function.

2. THE COMPUTATION OF EFFICIENT LENGTH

Having the economic diameter we can now determine the maximal efficient length over which the flow is no longer efficient. For this we substitute the economic diameter in the equations (1), (6) and (8). The cost of energy as a function of the length of pipe thus becomes:

$$E = \frac{c\tau}{\eta_c \eta_m 1000}\sum_{i=1}^{T}\left(\frac{1}{1+q_r}\right)^i \left\{\left[\frac{p_2}{\rho_2} - \frac{R}{n-1}\left(T_1 - T_2\right)\right]M_2 + \frac{8M_2^3}{\pi^2 \rho_2^2 D^4} + \right.$$
$$\left[\frac{p_2}{\rho_2} - \frac{R}{n-1}\left(T_1 - T_2\right)aD\left(\frac{p_m}{10^5}\right)^{1,3} + \frac{8M_2^2 a\left(p_m/10^5\right)^{1,3}}{\pi^2 \rho_2^2 D^3} + \frac{8\lambda R^2 T_m^2 M_2^3}{\pi^2 p_m^2 D^5}\right]L +$$
$$\frac{24\lambda R^2 T_m^2 M_2^2 a\left(p_m/10^5\right)^{1,3}}{\pi^2 \rho_m^2 D^4}L^2 + \frac{24\lambda R^2 T_m^2 M_2 a^2\left(p_m/10^5\right)^{2.6}}{\pi^2 \rho_m^2 D^3}L^3 + \tag{10}$$
$$\left. + \frac{8\lambda R^2 T_m^2 a^3\left(p_m/10^5\right)^{3.9}}{\pi^2 \rho_m^2 D^2}L \quad \right\}$$

The expenses due to compressors, assembly, and maintenance of the piping net are given by:

$$M = \left\{ \left(a + bD + cD^2\right)\left[1 + \left(q_0 + q_s + q_m\right)\sum_{i=1}^{T}\left(\frac{1}{1+q_r}\right)^i\right]L \right\} + C_{SC} \qquad (11)$$

where C_{SC} are the expenses due to the compressors:

$$\begin{aligned} C_{SC} = \left(P_{EC} + P_{RT} + P_{LC} + P_{IR}\right)\Bigg[1 + q_a \sum_{i=1}^{T}\left(\frac{1}{1+q_r}\right)^i + \\ + \left(P_{PS} + P_m\right)\sum_{i=1}^{T}\left(\frac{1}{1+q_r}\right)^i\Bigg] \end{aligned} \qquad (12)$$

where:
P_{EC} – price of compressor, electric engine and accessories;
P_{IR} – installation price for cooling system;
P_{RT} – price of buffer containers;
P_{PS} – price of exchange parts during recuperation period;
P_{LC} – price of construction for compressors station;
P_m – maintenance expenses;
$1/(1+q_r)$ – recuperation and updating expenses.

The air transport on a length *L* becomes inefficient when *E* is smaller than *M*. Under these circumstances it is more efficient to add a new compression station.

3. CONCLUSIONS

It was presented a theoretical model that can be applied also to other mechanical systems in order to get an economical improvement.
Optimal diameter expression founded here takes in the consideration the optimal operation for the system.
For economic reasons can be considered a new compression station, if the length of the pipes is too long.
The optimal solution is the one that replies both from economically and technically point of views to the improvement concept.

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SOME ASPECTS REGARDING AN ELECTROSTATIC CLEANER PROCESS OF MARINE OILS AND DIESEL FUELS

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This paper treats the problem of cleaning and reconditioning of waste oils and diesel fuels with mechanical impurities used in marine engines. The influence of different physical quantities involved in the electrostatic cleaner process are considered on the basis of dimensional analysis. The relative processing time is determined against the criteria, on which depends the kinetics of electrical separation in order to determine the efficiency of the process.

***Keywords**:* dielectric liquids, electrostatic oil cleaner, electroseparator, marine engines.

1. INTRODUCTION

Purging of dielectric liquids in electric fields is a current economical and ecological problem with applications in wide areas, such as the treatment of oils and diesel fuels used in marine engines. Currently are known different models of electroseparators [1-4], whose principle of operation is based on the action of the electric field on suspensions or emulsions prepared for purging.

In the majority of known electroseparators, submicron particles are crowded under the influence of the electric field, thus being easier to retain them. Electroseparators advantages are: low power consumption, no moving parts, high productivity, and retention of submicron particles. Less known from electroseparators category are the electroseparators with floating potential electrodes [5]. The classical method of electroseparation [1,2] is using mechanical filters interpose between electroseparator electrodes to retain the impurities. The electroseparators with electrodes with floating potential retain the impurities inside it, on the floating potential electrodes. This method can have both advantages and disadvantages, the need to study them being constant.

One way to study the electroseparators with floating potential electrode is to analysis the separation efficiency. The efficiency can be analyzed by dimensional analysis method. By such an analysis can be found the dimensionless similarity criteria that influence the process. These criteria can be grouped together to find an equation that expresses the electroseparation process.

2. ELECTROSEPARATION OF MECHANICAL IMPURITIES FROM DIELECTRIC LIQUIDS

In an electroseparation process of impurities from dielectric liquids, can be considered that the concentration of particles n in a dielectric liquid is depending on the initial concentration n_0, the final concentration limit n_f, the dielectric permittivity $\varepsilon_1\varepsilon_0$, density ρ_1 and kinematic viscosity of the dielectric liquid ν_1, radius of particles *a*, dielectric permittivity of these $\varepsilon_2\varepsilon_0$, the voltage applied to the electrodes u, the current density in the space between the electrodes j_0, the electric mobility of ions k and the time *t* [6,7].

These quantities can be grouped to form some dimensionless criteria [6,7]. The criteria 1-4 are analyzed in [6,7], in this paper being analyzed the rest of them:

$N_5 = \frac{\varepsilon_2\varepsilon_0}{\varepsilon_1\varepsilon_0} = \frac{\varepsilon_2}{\varepsilon_1}$, representing the ratio of the dielectric permittivity of the dielectric liquid and particles;

$N_6 = \frac{\nu_1\varepsilon_1\varepsilon_0 u}{j_0 \cdot a^3}$, which is the ratio of the relaxation time of the electrical phenomena in fluid $\tau = \varepsilon_1\varepsilon_0/\sigma_1 = \varepsilon_1\varepsilon_0 E/j_0 = \varepsilon_1\varepsilon_0 u(aj_0)$ at the mechanical relaxation time a^2/ν_1 at the scale of particle size;

$N_7 = \frac{4}{3}\pi a^3 n_0$, which is participation volume of particles in the dielectric liquid.

To simulate the influence of criteria $N_5......N_7$ to the relative concentration of particles n/n_0 and the relative processing time N_{8p}/N_{8p}^0 was developed a calculation software program in Mathcad 14 on the basis of our kinetic equation [6,7], which in the dimensionless form can be written as follows:

$$\frac{n}{n_0} = N_2 + (1 - N_2)\cdot \exp\left[-\frac{2}{3}N_3 \cdot N_4 \cdot \frac{2N_5+1}{N_5+2}\cdot\frac{1}{N_6}\cdot N_7 \cdot N_8\right]. \quad (1)$$

Were adopted the following fixed values of the criteria listed above: $N_5^0 = 2{,}083$; $N_6^0 = 3.057\cdot 10^7$; $N_7^0 = 5\cdot 10^{-4}$. Each of these criteria were successively varied at fixed values of the other criteria in the intervals: $0.2 \le N_5 \le 52.075$; $2.515\cdot 10^6 \le N_6 \le 3.057\cdot 10^9$; $5.5\cdot 10^{-5} \le N_7 \le 7.5\cdot 10^{-3}$ [6,7].

The results are presented in Figures 1-3.

The criterion N_5 is the ratio between the dielectric permittivity of the particles material, respectively the dielectric liquid material.

With the growth of this report, and therefore of the criterion N_5, the electric charge of the particles increases and with it the Coulomb force acting the electric field on them. This leads to reducing the processing time. However, the particles cannot upload an electrical charge however high.

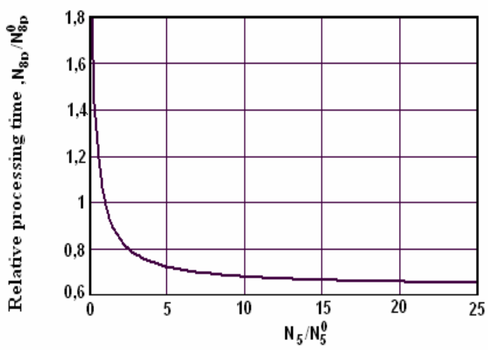

Fig. 1. The dependence of the relative processing time criterion N_{8p}/N_{8p}^0 on the criterion N_5

There is a limit of this charge that determines the self modeling domain of this dependence.

The criterion N_6 represents the relaxation time ratio of electrical phenomena in dielectric liquid $\tau = \varepsilon_1 \varepsilon_0 / \sigma_1 = \varepsilon_1 \varepsilon_0 E / j_0 = \varepsilon_1 \varepsilon_0 u / (a j_0)$ mechanical relaxation time a^2 / ν_1 at the scale of particle size. If N_6 is low, the electrical relaxation is independent of mechanical relaxation. This means that the processing environment respond more flexibly to the action of the electric field and the efficiency of electroseparation is higher. Therefore, reducing the criterion N_6 the amount of the processing time is reduced (Figure 2). The self modeling domain against the criteria N_6 is $0 \le N_6 \le 1{,}5 \cdot 10^8$.

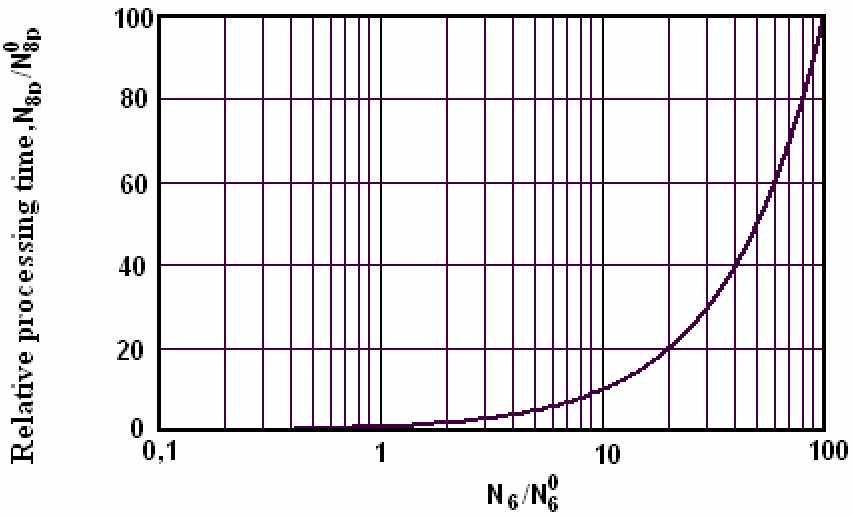

Fig. 2. The dependence of the relative processing time criterion N_{8p} / N_{8p}^0 on the criterion N_6

As shown in Figure 3, the processing relative dimensionless time is reduced by increasing the criterion N_7, that presents the initial density participation of particles in dielectric liquid. The nature of influence of N_7 criterion is similar to the influence of the mass concentration n_{m0}. The area where the processing time is self modeling by the criterion N_7 is $N_7 > 1.5 \cdot 10^{-3}$.

It is obvious that the relative concentration n / n_0 is self modeling of the criterion N_8 in the domain $N_8 > N_{8p}$, ie for times greater than the processing time $(t > t_p)$.

The analysis of graphs in Figures 1-3 allowed, on the one hand, determining dependencies n / n_0 and N_{8p} / N_{8p}^0 by other criteria of similarity and, on the other hand, identify areas of self-modeling of these dependencies by the similarity criteria.

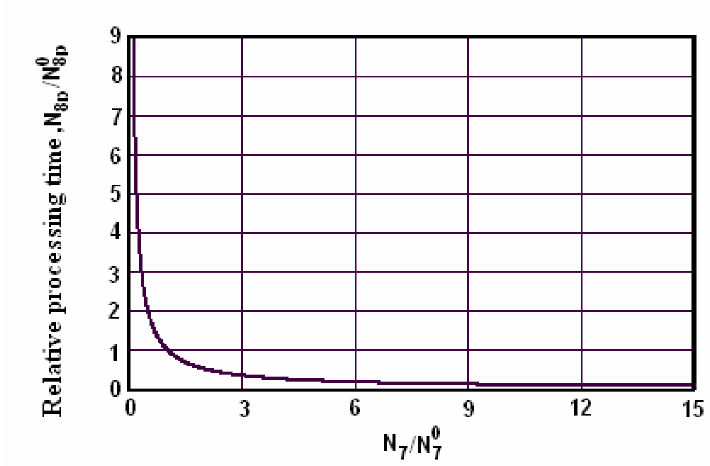

Fig. 3. The dependence of the relative processing time criterion N_{8p} / N^0_{8p} ***on the criterion*** N_7

3. CONCLUSIONS

Electrostatic oil cleaner of dielectric liquids in electric fields is a current problem with large area of applications, for example for cleaning and reconditioning of waste oils and diesel fuels with mechanical impurities used in marine engines, where this method can bring economic benefits.

Electrostatic cleaning of dielectric liquids, such as fuels and oils used in naval industry is an environmentally friendly method, because large quantities of liquids can be treated and reused.

To establish the influence of the dimensionless criteria on which depends the the electroseparation process, a calculation software was developed.

The analysis made in this paper is allowing to establish the areas of efficiency of this method.

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WATER DROPLETS ELECTROCOALESCENCE AND INSTABILITIES IN CLEANER PROCESS OF OILS AND FUEL OILS FOR MARINE ENGINES

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An analysis of water droplets electrocoalescence from a water-in-dielectric liquid emulsion, in an electrostatic oil cleaner process is maded in this paper. The efficiency of electrostatic purging of marine fuels and oils is analyzed. It is studied an electroseparator for dielectric liquids by own conception and the effect on water droplets instabilities under an electric field. It is studied a case that is not studied frequently, that of an inhomogeneous electric field. The process is simulated using CFD software with the capability to provide visual and mathematical data.

Keywords: electrocoalescence, dielectric liquid, emulsion, electric field, droplets, electroseparator.

1. INTRODUCTION

Water drops electrocoalescence is a process very common in oil industry where water-in-oil emulsion stability is an economically relevant issue [1-3]. This process can be used to purge fuels and oils used in marine industry too. At the separating plant, water droplets in water-in-oil emulsions have the diameter d=5-50μm. Using the force of gravity, settlers are not effective for separation of small droplets. Therefore by applying additional forces, particles trajectory and velocity is influenced. One method is to apply an electric field, a phenomenon which is helping to create larger droplets and to increase the efficiency of separation. It is known that [1] moderate turbulence that occurs in emulsion flow through electroseparator is critical in stimulating particle collision frequency and electrocoagulation efficiency.

By applying an electric field, droplets can coagulate but also can break, depending on certain parameters, as the electric field strength. Turbulence may promote droplets coagulation, but too high turbulence can lead to droplets break or spread, which can lead to a decreased separation efficiency.

For water-in-oil emulsions with water content up to 10.8% has been observed that the application of electric fields increase the efficiency of water separation from 51% to 77% of the total emulsified water [1].

2. MODELLING AND SIMULATION OF ELECTROCOALESCENCE

The physical model used for electrocoalescence process analysis consists of an electroseparator for dielectric liquids presented in Fig. 1. This electroseparator is designed to be used in industry for purging liquids in large quantities, but it can be used at small scale too, in microsystems or nanotechnology.

In this paper the dimensions are small enough with the scope to highlight the electrocoalescence phenomena between small water droplets.

The observed results can be extrapolated at another scale given the fact that with the increase of the dimensions between the electrodes, the only parameter that should be modified is the voltage at the electrodes in order to keep the same electric field intensity for which the water droplets comportment is known.

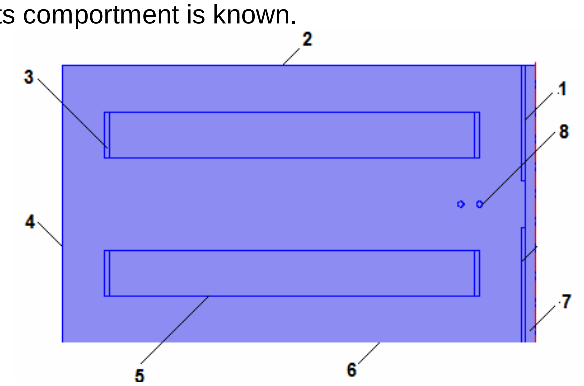

Fig.1. Physical model for water droplets electrocoalescence study, (2D axial symmetric section);

1 - insulation 2 - filtered liquid outlet, 3 - insulation, 4-electroseparator body (earthed), 5 - floating potential electrodes, 6- inlet for the impure dielectric fluid, 7-electrode with high potential, 8-water droplet

In Fig.1 is presented a schematic diagram representation for the physical model in 2D axial symmetric coordinates. An electroseparator for dielectric liquids is considered [4], consisting in a body (4) in the form of a vertical cylinder which has a height of 30 mm and 100 mm in diameter, filled with impure dielectric liquid. The bottom side of the electroseparator is the inlet (6) for the impure dielectric liquid and the top is the output (2) for the purged dielectric liquid. The electroseparator body is made of metal and is earthed. Inside to the electroseparator body (4) a centered high potential electrode (7) is placed, this electrode being insulated (1) with insulation which is interrupted by cross-cut slits to create a inhomogeneous electric field. Around the central high potential electrode, in electroseparator body and concentric with them, is positioned an intermediate group of 4 similar floating potential electrodes (5), as discs with central circular windows. The central circular windows diameter of these floating potential electrodes is 10 mm, the external diameter is 90 mm and their thickness is 5 mm. The horizontal distance between these electrodes is 10 mm.

The high potential electrode (7) and the floating potential electrodes (5) are made of copper. The cross-cut slits of high potential electrode are positioned symmetrically between the floating potential electrodes. Inner and outer edges of the floating potential electrodes are insulated with dielectric material.

The work fluid is characterized as an fuel oil-water and oil-water emulsions, liquid with known electrophysical properties: density ρ_2, relative dielectric permittivity ε_2 and average radius a of droplets in a dielectric liquid with the density ρ_1, relative dielectric permittivity ε_1 and kinematic viscosity ν_1 (properties of marine fuel oil type DMB: $\rho_1 = 880\,\mathrm{kg/m^3}$ at 15^{0}C; $\nu_1 = 8 \cdot 10^{-6}\,\mathrm{m^2/s}$ at 40^{0}C; $\varepsilon_1 = 2.20$; properties of marine engine oil type N22A:

$\rho_1 = 880\,\mathrm{kg/m^3}$ at 15^{0}C; $\nu_1 = 22\cdot 10^{-6}\ \mathrm{m^2/s}$ at 100^{0}C; $\varepsilon_1 = 2.70$; water droplets properties: $\varepsilon_2 = 81$; $a = 0.3\ \ mm$). Water droplets are considered as polar dielectric with behavior of conductor.

The electroseparation process is made in an electric field of an electrode system with cylindrical symmetry on which the stationary voltage U=5 kV is applied.

Subjected to an inhomogeneous electric field, the dispersed droplets will moves in the direction of the electric field lines of force.

To achieve the numerical calculus, the geometry is represented in 2D axial symmetric coordinates.

To describe the electrocoalescence of water droplets, Comsol Multiphysics software was used, with Electrostatics and Laminar-Two Phases Flow, Phase Field modules.

3. MATHEMATICAL MODEL

The electric force on the fluids is given by the divergence of the Maxwell stress tensor:

$$\vec{\mathrm{F}} = \nabla \cdot \vec{\mathrm{T}}\ , \tag{1}$$

where the Maxwell stress tensor is,

$$\vec{\mathrm{T}} = \vec{\mathrm{E}}\vec{\mathrm{D}}^T - \frac{1}{2}(\vec{\mathrm{E}}\cdot\vec{\mathrm{T}})\vec{\mathrm{I}}\ , \tag{2}$$

where $\vec{\mathrm{E}}$ is the electric fild and $\vec{\mathrm{D}}$ is the electric displacement field:

$$\vec{\mathrm{E}} = -\nabla\varphi\ ; \tag{3}$$

$$\vec{\mathrm{D}} = \varepsilon_0\varepsilon_r\vec{\mathrm{E}}\ . \tag{4}$$

If the modeling is performed in 2D space then equations for Maxwell stress tensor are,

$$\vec{\mathrm{T}} = \begin{bmatrix} \vec{\mathrm{T}}_{xx} & \vec{\mathrm{T}}_{xy} \\ \vec{\mathrm{T}}_{yx} & \vec{\mathrm{T}}_{yy} \end{bmatrix} = \begin{bmatrix} \varepsilon_0\varepsilon_r\vec{\mathrm{E}}_x^2 - \frac{1}{2}\varepsilon_0\varepsilon_r\left(\vec{\mathrm{E}}_x^2 + \vec{\mathrm{E}}_y^2\right) & \varepsilon_0\varepsilon_r\vec{\mathrm{E}}_x\vec{\mathrm{E}}_y \\ \varepsilon_0\varepsilon_r\vec{\mathrm{E}}_y\vec{\mathrm{E}}_x & \varepsilon_0\varepsilon_r\vec{\mathrm{E}}_y^2 - \frac{1}{2}\varepsilon_0\varepsilon_r\left(\vec{\mathrm{E}}_x^2 + \vec{\mathrm{E}}_y^2\right) \end{bmatrix}. \tag{5}$$

The relative permittivity is given by the equation,

$$\varepsilon_r = \varepsilon_{r1}V_{f1} + \varepsilon_{r2}V_{f2}\ , \tag{6}$$

where V_{f1} and V_{f2} are the volume fractions of each fluid; ε_{r1} and ε_{r2} are the relative permittivity of oil and water.

4. DROP INSTABILITIES ANALYSIS

As tested liquids in modeling are used the marine engine oil N22A with water droplets with properties presented in p. 2.

The distance between droplets is d = 2 mm. At the inlet the fluid velocity is u =50 mm/s. In the area where the droplets are, the value of the electric field is between 1.5-3.5 kV/cm.

In Figure 2 are presented the results for simulation of volume fractions of water droplets in a marine engine oil-water emulsion. The electric field lines of force, on the surface of the droplets, have a dynamic behavior showing the electric field influence to water droplets.

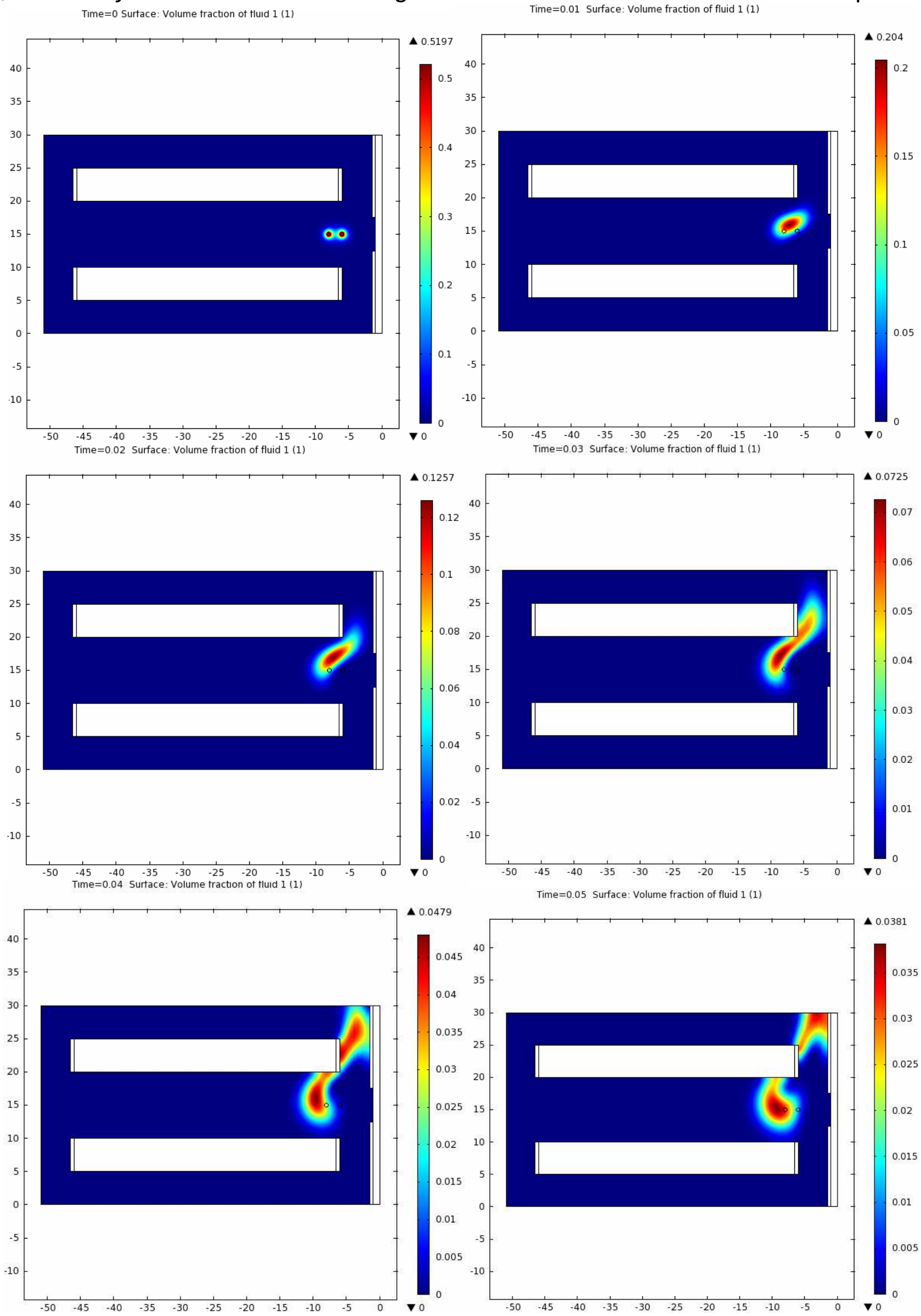

Fig. 2. Volume fraction of fluid at t=0; 0.01; 0.02; 0.03; 0.04; 0.05 seconds

Under an electric field influence, appropriate water droplets will approach each other until they touch. At this moment droplets will coagulate under the influence of tension forces from the surface, the same forces opposing to the force exerted by the electric field which work to break the newly created drop.

Droplet stability in an electric field is given by the balance of these forces. Water droplets are deforming in an electric field and will elongate into the direction of the electric field lines of force, until to a point where the drop becomes unstable and breaks. This point of electric strength where droplet breakage occurs is called critical intensity E_C [6].

Maximum elongation that a drop can reach is given by the ratio of major axis lengths a with the minor axis of the drop b. The maximum ratio at which the drop is stable is $a/b \cong 1{,}9$ [7].

If this value is eceeded, the droplet will became unstable. The critical electric field intensity at wich the droplet will became unstable is given by the equation,

$$Ec = 0{,}648\sqrt{\frac{T}{2\varepsilon_2 a}} \quad , \tag{7}$$

where T is the surface stress tension at the surface of the droplet.

Analyzing the obtained result from Figure 2, we can observe that the time for droplet electrocoalescence is very short, less than one second. Because the droplets are very close, droplets will electrocoalescence. The newly created droplet is breaking very fast, under the influence of hydrodynamic and electric field forces.

We can observe that not all droplets are attracted to the electroseparator electrodes, and with time theese droplets tend to break, in good agreement with Ec. (7). If droplets migrate in a zone with a high electric field, there is a risk that droplets formed by coalescence to break in a higher number of thiny droplets as they were originally, if it is used a much high voltage, or even at the same voltage.

Water droplets will coagulate very fast in electroseparators with similar geometry as the electroseparator presented above, but we can observe that in the same time chain of water can appear between electrodes, leading to failure of the device.

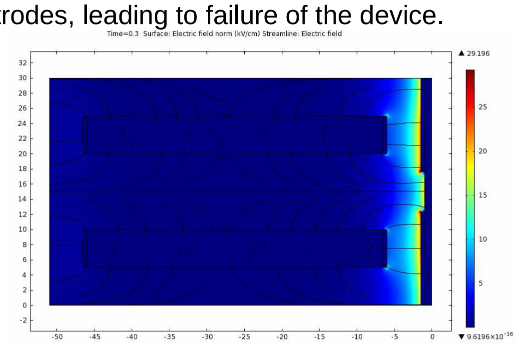

Fig. 3. Electric field lines of force repartition inside of the electroseparator

An important parameter which is not frequently considered in electroseparatoring process is the multiphase flow velocity. We can observe from the simulation, that the electroseparator is very efficient in coagulating water droplets. But in the same time, at high values of the electric field, water with oil can create an emulsion, which is trapped between electrodes.

So is recommended to evacuate the newly created droplets, and to retain the water outside of the electroseparator by using auxiliary methods.

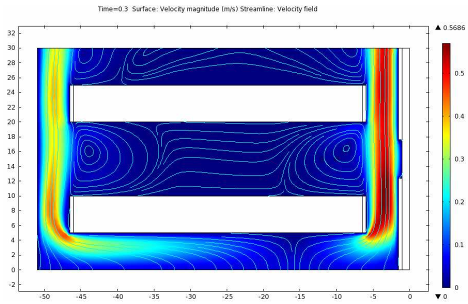

Fig. 4. Fluid lines of velocity repartition inside of the electroseparator

Analizyng the images from Figures 3 and 4, we can observe that in the start zone where inittialy were considered water droplets, a vortex is created by the flow of the fluid. Comparing the images from Figure 2 with Figure 3 and Figure 4, we can have a better understanding of what is happening with the new created water droplet.

5. CONCLUSIONS

It was analyzed the behavior of two water droplets and the electrocoalescence process in an electric field created by an electroseparator for dielectric liquids.

It was proved the utility of using CFD simulaton programs to analyze the electrocoalescence phenomenon.

By using electric fields of adequate intensity, water droplets will coalescence and may be attracted to electroseparator electrodes.

A biggest number of water drops or high electric field intensity can adversely affect the process of electrostatic oil cleaning.

In design calculations of electroseparators should be considered the critical value of the electric field between the electrodes at which water droplets became instable in the dielectric fluid, because this will create difficult conditions for purging the oil.

It was shown that fluid velocity can be an important parameter in electrostatic oil cleaner.

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OPERATIONAL MANAGEMENT WITH APLICABILITY ON ANTIFOULING MARITIME ECOLOGICAL SYSTEM

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The triggering mechanism of tin copolymer antideposit products for hull protection was reproduced in a system based on the unique technology that uses copper acryl. Similar performance levels of antifoulling (that can last up to 3 years) are results of a new tin free system for coastline ships. The auto-polishing characteristics of copper acryl result from a controlled hydrolytic process, which is similar to the tin copolymer triggering mechanism. The active agent releasing level is sustained throughout the lifetime of the cover, by the chemical control of size and composition of the active zone. Performance characteristics are specially designed for coastline ships, the sustained releasing level of the biocide substance is made for long docking periods and high levels of antifoulling levels permit maximum efficiency for operating ships.The economic and environmental benefits are done by giving up to usual antifoulling auto polish substances and using Ecoloflex instead. Thus money is saved by reducing fuel consumption and environmental taxes. Ecoflex antifoulling systems contain only copper based biocide that decays fast when released in a marine environment.

Keywords: copolymer, antifoulling,Ecoloflex, maritime technology, ecological application.

1. INTRODUCTION

The purpose of this paper is to describe how the operating mechanism of anti-deposit products with self-polishing based copolymer was translated in tin Ecoloflex new product based on copper acrylate copolymer used for coastal vessels. Performance characteristics of cement made of tin containing copolymer is a support for supporting the biocidal substance release level and to maintain the level of self-polishing. This key function was successfully reproduced by self-polishing mechanism based on tin without unique patented technology that uses copper acrylate contains no toxic TBT(Tri-Boutil-Toluen).

2. MANAGEMENT OF ACTUATING MECHANISMS

Technology created anti-deposits with self-polishing Ecoloflex is based on the system binder containing acrylate of copper with controlled release that has no rival among current technologies without tin. Very high performance of the products anti-deposits on the basis of tin are achieved by the system. The characteristics of the self-polishing are made through the combination of a mechanism of loss by diffusion controlled of the active substance of the paint film and a reaction to controlled chemical hydrolysis. The result is a product anti-deposits with selfpolishing with a level for the release of the substance biocides controlled and constant in time.

3. THE MECHANISM OF CONTROLLED HYDROLYSIS

In immersing in sea water to the treated areas with acrylic copolymers of copper and tin the hydrolysis processes take place similar. The sodium ions Na+ from sea water penetrates the surface of tin by releasing copper copolymer grouping TBT^{+}[1] , utilising a salt soluble the tin of this copolymer. Species results of biocides $TBT^{+}Cl^{-}$ are issued in sea water. In a similar manner to immersion copolymer of acrylate copper anti-deposits salt soluble sodium is formed on the surface. Group to be issued is incorporated in RCO2-Na+ and the copper carbonate basic ideal of the composition of Cu2 [OH-] +3Cl- + [Cu(H20)6] 2+Cl2- , but at a concentration sufficient to achieve an effective biocidal . Both reactions ,hidrolizarea and the exchange of ions, which are produced in these systems are taking place in the sea while the second reaction is depending on the ph of sea-water.

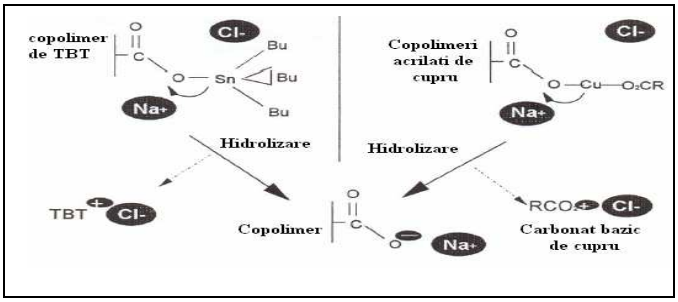

Fig. 1. The actuators comparable to acrylic copolymer coating of tin and copper

4. THE MECHANISM OF SELF-POLISHING

The mechanism of the self-polishing of the products on the basis of acrylical copolymers of copper and tin is controlled by the rate of diffusion of the hidrolised polymer on the surface of sea water[2]. A substrate in which it occurs the laminar flow sea water expands away from the surface polymer. The thickness this undercoat is inversely proportional with ship's speed. The concentration of polymer hydrolysates thereof decreases along undercoat to maximum to the concentration that is found in the table of polymers to minimum concentration in sea water. The diffusion rate is directly proportional to the concentration gradient along the substrate. Therefore concentration gradient is directly proportional to the ship's speed. In consequence there is a linear dependence of the level of polish in both systems together with a loss of the film positive, even if the ship is stationary (see figure 2).

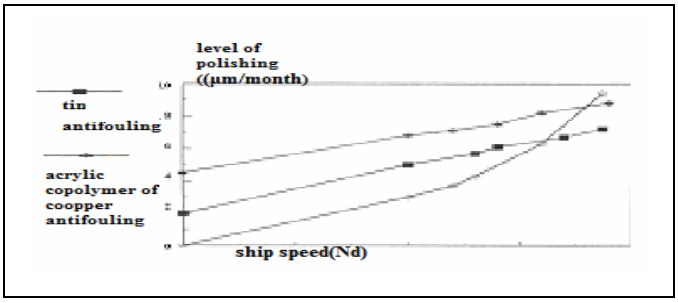

Fig. 2. Comparison of dependence level of polish to the travel speed of the ship between the products without conventional tin and those on the basis of copper and tin

5. PERFORMANCE CHARACTERISTICS OF COASTAL SHIPS

Products anti-deposits with self-polishing on the basis of acrylate copper- Ecoloflex have been introduced by the International Paint [1,3] for application to coastal vessels. Performance characteristic attributed to this system are designed to meet operational profile and to meet the requirements of plant deposits in any conditions [fig.3].

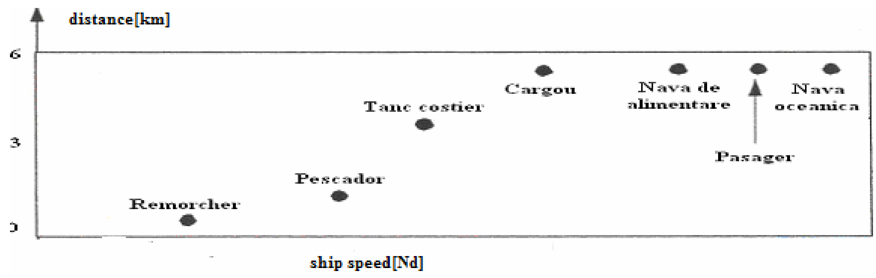

Fig. 3. Operational Profile rib for the categories of speed and depending on the activity

Table 1: Comparison beween conventional product and Ecoloflex

Performance characteristic	**Conventional product without tin**	**Ecoloflex with copper acrylate**
Antifouling performances	Average 70-74%	Media awaited is over 90 %.
The life	Max.3 years	In 3 years
Efficiency of the use paint	Unlinear dependence on the speed of the polishing leads to excessive leakage in the film at high speeds	Loss of the film in static conditions
Properties of the surface before application	Surface preparation prior to application of require high cost and long time allotted to it.	Minimum cost of preparing the surface prior to application shell.

6. CONCLUSIONS

Conventional products without tin the yield of 72% performance is satisfactory. On the other hand ships which have used products based on copolymers of tin the efficiency is 96 %. Dramatic improvement in performance on systems without tin has the importance both to help reduce the cost of fuels they obtain operators of vessels as well by reducing environmental damage , brought to the whole coastal fleet. We observed the following: 1} average fuel consumption per day is 17 tonnes, at a price of 100 USD per tonne[4,5]; 2) Conventional Products are up to 18% less efficient than Ecoloflex when you take into account engine power and fuel consumption; 3) have been analyzed activity for 85% of the ships.possible benefits resulting from environmental fuel savings include reduction of emissions of pollutants such as: carbon dioxide(3.802.100 tonne/day for conventional product and 192.500 tonne/day for Ecoloflex) and sulfur dioxide(995.000 tonne/day for conventional product and 50.750 tonne/day for Ecoloflex).

Changeover to the new products Ecoloflex satisfies both economic conditions as well as environmental benefits , satisfying needs of the coastal operators . Satisfactory performance levels greater than 90 % and guarantees to the life more than 36 months are provided for the technology Ecoloflex. Levels of performance levels are expected to increase to more than 90 % in 12 months as more information arises from the ships that use this technology.

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ONLINE TRAINING FOR HIGHER EDUCATION

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Last years showed an increased interest on the concept of life long learning, especially in the European countries. Many activity fields, including maritime area involve this concept.
A modern society must keep the level of knowledge of its citizens continuously updated to actual development, mainly in the fields of interest. This requirement can be accomplished by teaching and studying solutions that will use all available options including internet.
The present paper is showing on already applied online teaching system used by our university, designed to offer easy access to information for teachers and students, but also available for former students, now officers onboard ships, in order to be able to update latest information's about technical development in maritime field necessary in their duty activities.
The online teaching techniques are used for the development of the concept "train the trainers" in our university for younger lecturers, to help them to integrate in the academic training system, through the project named "Seafarers' environmental, social and cultural implications of sharing life on board ship within multinational crews – SeaCultLife", dedicated to the development of the younger and experienced lecturers competencies related to the training domain requirement and also development and improvement of the skills in using of the newest teaching and training techniques.

***Keywords**: O*nline teaching, knowledge's development, maritime field, life long learning, modern technology

1. INTRODUCTION

In the present, inside of the training system are used two concepts of teaching and training, in generally, the traditional concept, based on paper text and courses audition and the modern concept, using computerized technologies, as simulators, virtual reality and online courses. Both concepts are usefully, because not all types of information can be communicated using solely the traditional or the modern one.

There are knowledge, as fundamentals, which are better developed using the traditional concept, where the teacher expresses clearly the terms, definitions, formulas and interact with the students for a higher understanding.

On the other side, courses developed especially for specialization or for upgrading of the knowledge, after finishing of the academic training, can be more easily communicated through the modern technology, as online or distant learning. In this case it is considered that the receivers of information already have the fundamental knowledge and these new information come to complete it.

Also, the online teaching techniques are more accessible for persons involved in the social and economical life of civil society and do not have enough time to attend the classes.

The modern society need citizens more trained and specialized for its evolution and development. These requirements can be covered through a better opening of the scholar system, at all levels, to the civil society.

An important mission of the system, mainly of the academic level training system, is to ensure the necessary techniques and information volume for a more educated society, with a higher level of knowledge, in a continuous contact with the latest researches and technical development.

The completion of this mission can have benefits for the system itself, offering possibilities to bring inside persons with a higher level of knowledge, able to improve and continue the development of the present methodologies.

One of the activity field intensive interested in this learning opportunity, the online procedure, is the maritime field. Here, the characteristics of activity cannot allow the direct presence in the classes for improving of the existing knowledge and skills. In the last decades, the changes, especially technically, have been produced, making necessary a periodically improvement and update. The online teaching techniques represent the better solution for this case, the internet being accessible from the middle of the ocean now.

2. THE ONLINE LEARNING OPPORTUNITIES

In the present days, the computers and computerized programs are part of the life for many people. The computerized technologies became indispensable for many activity fields, computers being part of the production processes, or even the essence of the work.

Taking these aspects in consideration, to put the school in the virtual environment seems to be a good idea. In many cases, the interaction between person and computer is more benefic than an interaction person to person related to the process of information and knowledge transfer. The computerized information is taking as impersonal by the receiver and can be interpreted and adapted to the own perception. When the same information is expressed by a person, than can become personalized, the sender putting belong the information, his own remarks or opinions.

Other important characteristic of the online learning is giving by the possibility to have access to the information all the time, according with the user schedule. This option is value for those persons who have a heavy life program, for who the regular teaching schedule is difficult to be kept. This is one of the possibility offers by the online learning technique with a great importance in the maritime activity, where the program is made under the local time, ship hours, mostly different by the school local time.

An advantage of the online learning is represented by the possibility of different computerized programs correlation inside of the same course. This lets the user to access the necessary technologies more easily from one place, not needing to change places for each in part. In this way, it is possible to develop the online courses for initial or specialized training which requests the use of the simulation technology or designing programs.

Our university experiences this option inside of a course for familiarization training for petroleum tanker ship operation. Inside of the online course, the students and already certified seafarers interested to attend to a job on a tanker ship, have the possibility to visualize simulated application regarding different operation necessary to be known on a tanker ship, previously, reading and learning the theoretical modules about these.

Using the online teaching techniques, the student or trainee has the possibility to access more courses on the same time, option to take all the information one time and cover the curricula in a shorter period than will be done during the regular classes.

The communication between trainers and trainees can be done through different ways, using the electronic correspondence or an open forum for general impressions and opinions. These communication procedures can help to the improvement of the present data and to generate the development of additional subjects with role of covering of missing date or useful information for the main course.

Taking into account the actual trend in technology and techniques development in the maritime field, this kind of informative issuing can realize a continue and constant flow of information to the interested people, involved in ship operation and maintenance.

The online learning benefits can be summarized as follows:

- The student can attend a course at anytime from anywhere in the world that has internet access, according with his own schedule. This option is value for those persons who have a heavy life program, for who the regular teaching schedule is difficult to be keep. This is one of the possibility offers by the online learning with a great importance in the maritime activity, where the program is made under the local time, ship hours, mostly different by the school local time.
- The course material is accessible 24 hours a day 7 days a week. The students have the ability to read and reread lectures, discussions, explanations and comments. Using the online teaching techniques, the student or trainee have possibility to access more courses on the same time, option to take all the information one time and to cover the curricula in a shorter period than will be done during regular classes.
- In an online environment, attendance to class is only evident if the student actually participates in classroom discussion. This increases student interaction and the diversity of opinion, because everyone gets a say, not just the most talkative.
- Online instructors come with practical knowledge and may be from any location across the globe. This allows students to be exposed to knowledge that can't be learned in books and see how class concepts are applied in real business situations.
- Participating online is much less intimidating than in the classroom. Anonymity provides students a level playing field undisturbed by bias caused by seating arrangement, gender, race and age. The students can also think longer about what they want to say and add their comments when ready. In a traditional class room, the conversation could have gone way past the point where the student wants to comment. In many cases, the interaction between person and computer is more benefic than an interaction person to person related to the process of information and knowledge transfer. The computerized information is taking as impersonal by the receiver and can be interpreted and adapted to the own perception. When the same information is expressed by a person, it could become personalized, the sender putting belong the information, his own remarks or opinions.
- The online environment makes instructors more approachable. Students can talk openly with their teachers through online chats, email and in newsgroup discussions, an open forum for general impressions and opinions, without waiting for office hours that may not be convenient. These communication procedures can help to the improvement of the present data and to generate the development of additional subjects with role of covering of missing date or useful information’s for the main course. Also, his option for communication provides enhanced contact between instructors and students.

- Online course development allows for a broad spectrum of content. Students can access the school's library from their PC's for research articles, ebook content and other material without worries that the material is not available.
- Critical to the explosion in the online field is the increasing number of programs and courses now available.

3. THE LONG LIFE LEARNING CONCEPT AND PRINCIPLES

Long life learning is a term that is widely used in a variety of contexts; however its meaning is often unclear. The term recognizes that learning is not confined to childhood or the classroom, but takes place throughout life and in a range of situations. During the last fifty years, constant scientific and technological innovation and change have had a profound effect on learning needs and styles. Learning can no longer be divided into a place and time to acquire knowledge, the school and a place and time to apply the knowledge acquired, the workplace.

Also, life long learning is used for combining formal, informal and non-formal education and training, with a reconsideration of professional recognition and quality assurance processes. It is the process of acquiring and expanding knowledge, skills and dispositions throughout the life to foster well-being.

Long life learning is viewed as all-purposeful learning activity, undertaken on an ongoing basis with the aim of improving knowledge, skills and competence. Such learning contributes to promote both employability and active citizenship and combating social exclusion.

The philosophy of education system is now changing globally and rapidly towards a continuous learning process. The change in the education system opens up the opportunity of part-time higher education in vocational and non-vocational streams. Life long learning puts emphasis on the initiative, zeal and motivation of learners to educate himself/herself according to his/her space, need and time rather than on the educators. Its necessity arises out of quest for knowledge, recognition, needs to solve many of his/her problems and develop capability and competency to survive in society and market place. In a professional discipline, the need for long life learning is more to prepare own person for fast changing professional competencies.

Long life learning is, thus, a philosophy that makes one to learn throughout the life of an individual either formally or informally. The informal learning process takes place through various ways and means such as observation, experience, environment and the need of individuals. The formal learning process is through well defined, structured method of education. In this context, the continuing professional education plays a catalytic role augmenting the method of long life learning.

In October 2006 the European Commission published a Communication entitled "Adult learning: It is never too late to learn". This document suggests long life learning to be the core of the ambitious Lisbon 2010-process, in which the whole of the European Union should become a learning area. In December 2007, the European Parliament's Committee on Culture and Education published a "Report on Adult learning: It is never too late to learn", which recognized the Commission Communication and a number of related recommendations and resolutions, and which urged member states to establish a long life learning culture.

Corroborating the European Commission policy with the population ageing of European countries, the role of lifelong learning and the educational system position near this situation must be an important one.

Putting together the social and economical conditions, economical being prior, and the opportunities creates by the online teaching procedures the development possibilities of this lifelong learning concept increase considerable.

In an informative society, the use of the latest technology inside of the learning process, at any age, is the easiest and cheapest way of knowledge's propagation.

4. THE FORMATION OF LECTURERS TO PROVIDE ONLINE TEACHING

The principal providers of the long life learning in this moment, all over the world, are the universities and associated graduate institutions. At this level, there are possibilities to create and develop material, as courses and practical applications, for graduates of the same or inferior level.

To provide the necessary knowledge for a specified activity domain is most important to have your own trained persons, as lecturers, as institution. Taking into account the differences between this kind of learning and the formal learning, it is obviously requested to institution to have persons in charge with necessary skills for this.

In this idea, the previous step in creation of the learning curricula is the process of train the trainers to be qualified for this activity.

Constanta Maritime University developed a project dedicated to formation of the lecturers, younger and experienced, in the new teaching technology, to acquire and improve the present skills and knowledge about the new forms of learning, including online learning techniques and providing of training for graduate persons.

The "Seafarers' environmental, social and cultural implications of sharing life on boardship within multinational crews – SeaCultLife" project is based on politics and strategies fated to support the European maritime academic system position into the worldwide context.

The project is developed according with the Lisbon European strategies with the scope to make from European Union a dynamic and competitive community with an economy based on knowledge, with much and better working places, increasing investment in education and research activities. For this purpose, the Commission in relation with the member states and universities put into practice concrete actions related to continue professional formation in the educational field.

Starting from 2001, once the e-Europe plan has been launched, through e-Learning initiative, the communication and computerized technology became an important element of educational system.

All of these strategies opened new possibilities for universities and their staff, as increasing of quality in academic level, professional promotion to easement the economical grow and develop of society based on knowledge.

European Commission considers the maritime transport development as an important element in general economical growing. In this context, the maritime training system is the part which offer qualified work force on the European market.

Also International Maritime Organization put accent on the level of training in the maritime educational system. With the latest intentions of changing of the levels of training, in order to improve the STCW Convention, it appeared as necessary to be known the actual equipments and technologies met onboard ships. These requirements need people trained and familiarized with equipments, able to train the others.

The development of the maritime industry imposes the implementation of a framework for providing of advancing programs due to continue changing of this activity domain.

Beside general objective of the project, the specifically objectives are:

1. Increasing of lecturers competencies through promotion of knowledge and technologies in the academic maritime field.
2. Creation of a development, update and on-line management framework for initial and continue formative of the human resources.
3. Realizing of studies and analyze to define formative programs dedicated and an optimum correlation of these with maritime industry necessities.
4. Increasing of access and participation of lecturers to formative programs and to obtain a double qualification.
5. Encouraging of lecturers to maintain a high qualification level through participation at specialized courses.
6. Introduction of carrier advancing opportunities for younger lecturers.
7. Verifying of the process and teaching activities through initial and continue formative programs in scope of improvement of TIC using level.

All these objectives are based on the premise that continue learning is the main condition for restructuring and development of educational and formative systems, for assuring the decisive competencies during life and to realize the coherency among persons involved in the maritime academic system.

A high level of qualification has to be guaranteed by the training institutions through modular and flexible educational structures, completed with high standard personnel.

This project tries to involve maritime lecturers in international maritime transport framework, to put them in direct contact with the end users of their work, the companies from maritime industries and to know exactly their needs. The international maritime companies are the necessary source of information regarding worldwide requests for employ of the maritime personnel.

This information is used to know what are the actual requirements for the new enters in the maritime field, younger officers, also, to have acknowledge about the necessary skills and knowledge requested to the present acting persons. In the first case, the completion of the training for the maritime officers is done during the academic school years through the regular courses according with the international required curricula.

For the acting persons, with years of experience in the field, the training process is commonly based on courses and updated information that can be combined or added to the existent knowledge.

Most of these materials are provided online using our own web portal, access being free or using identification element, offered by the trainer lecturer.

During time, the users number of this portal has tripled, the biggest number being represented by the former students or seafarers interested.

5. CONCLUSIONS

In the present context of society, development is necessary to have people trained at the higher level and to maintain the training level from the begging to the ending of their activity. For this reason it is compulsory to develop or create systems able to provide adequate training and to offer possibilities to acquire new competencies and knowledge during life.

The use of the newest techniques as online and distant learning, combined with the traditional forms of training, or based on these, seems to represent the optimum solution for a better and high quality learning system inside of the life long learning concept.

The learning system requests trainers and lecturers capable to offer the necessary learning materials for the process. Constanta Maritime University started programs dedicated to the life long learning, based on a series of online courses and in parallel in order to improve its capacities for this learning method, training lecturers to be able to offer in the future the requested knowledge and information for the people involved in the maritime industry.

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